Sustainable Society for the Saving Unique Biodiversity and Very Rich Biological Resources of the Caspian Sea

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CONTENTS

Physical environment of the Caspian Sea

The Caspian Sea is a lake with no outlets, which is washing shores of the five countries: Azerbaijan, Iran, Turkmenistan, Kazakhstan and Russia (Fig. 1).The Caspian Sea is the largest lake in the world, both by its area and volume. Its watershed is approximately 3.5m km^2. The level of the Caspian is lower than the mean sea level (M.S.L.). However, it is fluctuates depending on the water balance (Table 1). In the 20th century it has been fluctuating within the range of almost four meters, approximately from -25 m in the beginning of the century to -29 m in 1977. In the end of the 20th century, the sea levels unexpectedly soared, and in the beginning of the 21st century began to drop again. Because of inconstancy of Caspian levels, its area is also inconstant (Fig. 17).

The Caspian Sea is divided into three parts: Northern, Middle and Southern. Although all these three areas have approximately equal areas, their volumes are extremely different (Table 2).

The Northern Caspian is the shallowest and the smallest by its volume. Its area makes about 29 % of the entire area, though its volume makes less than 1%. The area of the Northern Caspian varies from 92750 up to 126596 km^2, and its average volume makes 900 km^3. The average depth of the Northern Caspian is 6 meters, and maximal depths do not exceed 10m. About 20 % of the area of the Northern Caspian have the depths less than 1 m (Zonn, 2000).

The area of the Middle Caspian makes about 36 %, and its volume – about 35 %. Its area varies from 133560 up to 151626 km^2, and the average volume makes 26400 km^3. The average depth of the Middle Caspian is about175 m, and the greatest - 790 m (Zonn, 2000).

The Southern Caspian has the largest volume –some 64 % of the total volume, and its area amounts to 35 % of the total area. It is the deepest part of the sea with the maximal depth reaching 1025 m. The area is from 144690 up to 151018 km^2, and the average volume - 48300 km^3. The average depth is 300 m (Zonn, 2000).

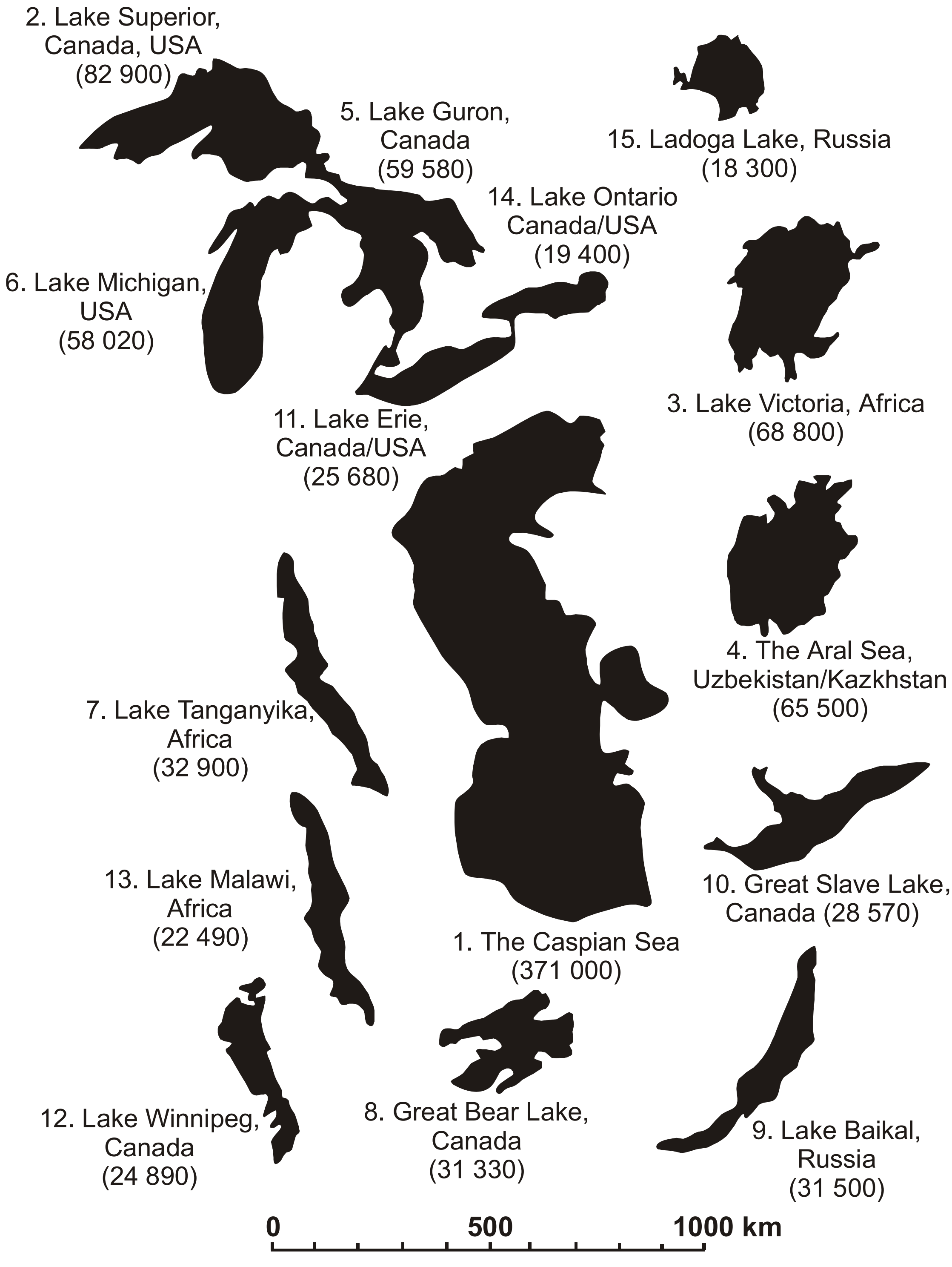

Figure 1. Caspian Sea regarding the largest lakes of the World. In the brackets there is area in sq. km, area of the Aral Sea is given for 1960. *(By Mary J. Burgis and Pat Morris "The Natural History of Lakes", 1987)*

Table 1. Wate balance of the Caspian Sea (according to R.E. Nikonova). Volume (km^3) / level change (cm).

Years	Inflow form rivers	Underground inflow	Precipitations	Evaporation	Outflow to Kara Bogaz Gol	Balance (per year)
1900–1929	332.4	5.5	69.8	389.4	21.8	-3.5
	82.4	1.4	17.3	96.7	5.4	-1.0
1930–1941	268.6	5.5	72.9	394.8	12.4	-60.2
	68.3	1.4	18.5	100.4	3.2	-15.4
1942–1969	285.4	4.0	74.1	356.3	10.6	-3.4
	77.3	1.1	20.0	96.4	2.9	-0.9
1970–1977	240.5	4.0	87.6	374.9	7.1	-49.9
	66.7	1.1	24.3	103.9	2.0	-13.8
1978–1990	306.6	4.0	86.1	343.7	1.8	51.2
	81.9	1.1	23.0	91.8	0.5	13.7
1942–1990	283.6	4.0	79.9	357.8	7.7	2.0
	76.3	1.1	21.5	96.3	2.1	0.5
1900–1990	229.0	4.0	76.6	376.6	13.0	-10.0
	77.0	1.1	19.7	97.0	3.3	-2.6

Table 2. Main parameters of the Caspian Sea.

Parameters	Caspian Sea	Northern Caspian	Middle Caspian	Southern Caspian
Volume, km^3	77000			
Volume, %	100	0.94	35.39	63.67
Area, km^2	436000			
Area, %	100	27.73	36.63	35.64
Max. depth, m	1025	10	770	1025
Mean depth, m	184	6.2	175.5	325
Max. length, km	1204			1204
Max. width, km	566			566
Mean width, km	204			204

Except for the above three areas, the fourth is distinguished in the Caspian. It is a shallow gulf, Kara-Bogaz-Gol (Fig. 2) with maximal depths not exceeding 10 m. Its area is about 15000 km^2, amounting to more than 3 % of the total area of the sea. The gulf is connected with the Middle Caspian by a narrow strait. The role of the gulf in the water balance of the Caspian is quite great. This shallow gulf is lower than the level of the sea approximately by 3-4 meters and due to this the sea constantly drains into it. This water quickly evaporates on boundless extents of this shallow gulf. Thus, this gulf is a large evaporator of the Caspian Sea playing an important role the water balance. Along with this water salt is brought in from the sea.

Figure 2. Caspian Sea water area. *(by Rodionov, 1994)*

The water balance of the Caspian is mainly determined by river runoffs and rainfalls (it is its incoming part), evaporation and water outflow into Kara-Bogaz-Gol (it is its outgoing part). The ground water runoff into the Caspian is insignificant and this incoming component of the water balance is frequently disregarded. The incoming part is almost completely counterbalanced with evaporation, of which the discharge into Kara-Bogaz-Gol makes only 5%.

More than 130 rivers flow into the Caspian, but only 9 of them have a delta. The most important part of the incoming part of the water balance is the river runoff of the Volga, which makes almost 80 % of the total riverine inflow. The average long-term runoff of the Volga passing through the Volgograd Hydroelectric Station is evaluated at the level of 251-254 km^3. The range of fluctuations during the whole period of instrumental observations has made more than 200 km^3 since 1881. The delta of the Volga is the largest delta on the Caspian. Another large river flowing into the Caspian is the Terek (discharge 8.5-11.4 km^3). Its delta is almost half the delta of the Volga. The river Sulak (discharge 3.6-4.0 km3) has a very small delta. These rivers flow at the territory of the Russia. Two big rivers – the Kura (discharge 13.0-15.5 km^3) and the river Samur (discharge 2.7 km^3) flow into the Caspian in Azerbaijan. Eastern coast of the Caspian is almost absolutely deprived of a hydrographic network. At present, only the river Ural (discharge 6.6-8.1 km^3) flows into the Caspian at the territory of Kazakhstan. Its delta is almost four times less than the delta of the Volga. Nowadays Emba River reaches the Caspian only during high water years. In Turkmenistan, there is only Atrek River flowing into the Caspian. This river often dries in its lower stretches, and its waters reach the Caspian only in spring. Its average yearly runoff is less than 0.24 km^3. The largest river of Iran flowing into the Caspian is the river Sefidrud (discharge 3.93-4.67 km^3). Its delta is ten times less than the delta of the Volga.

Precipitation is distributed unevenly over the Caspian. In the average the Caspian receives some 100 mm of rainfalls per year. The minimal amount of rainfalls is observed at eastern coast, less than 90 mm, at northern - less than 300 mm, at western from 400 up to 600 mm, at southwestern – 1600 mm.

The major abiotic parameter of the Caspian Sea is its salinity (Fig. 3, 4, 5). The average salinity of the Caspian is equal to 12.85 g/l. However, all areas of the Caspian: Northern, Middle, Southern and the gulf Kara-Bogaz-Gol differ with the salinity of their waters.

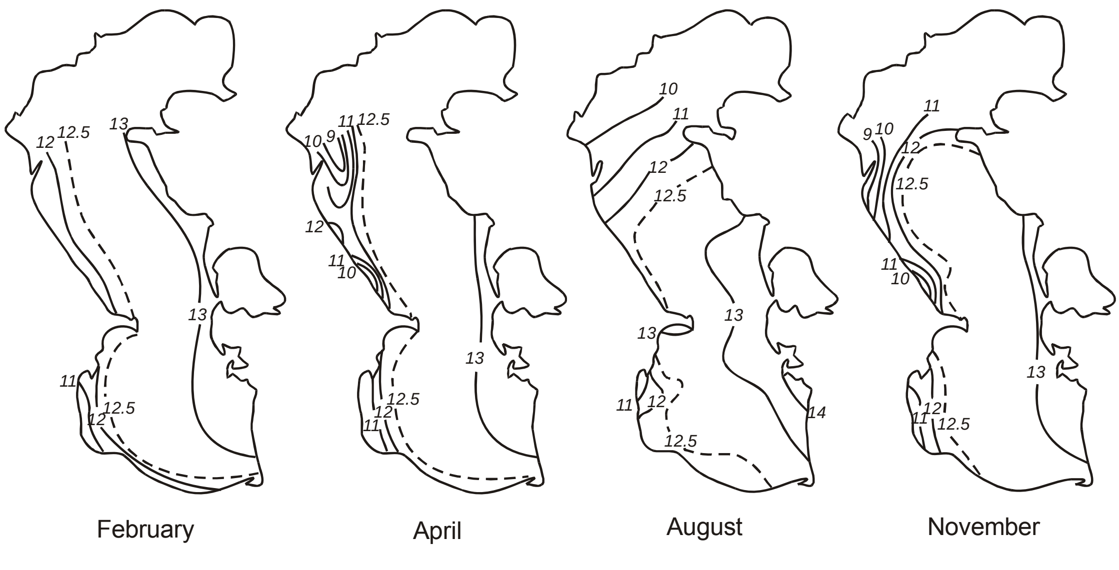

Figure 3. Mean salinity (g/l) on the surface in the Caspian Sea. *(by Zenkevich, 1963)*

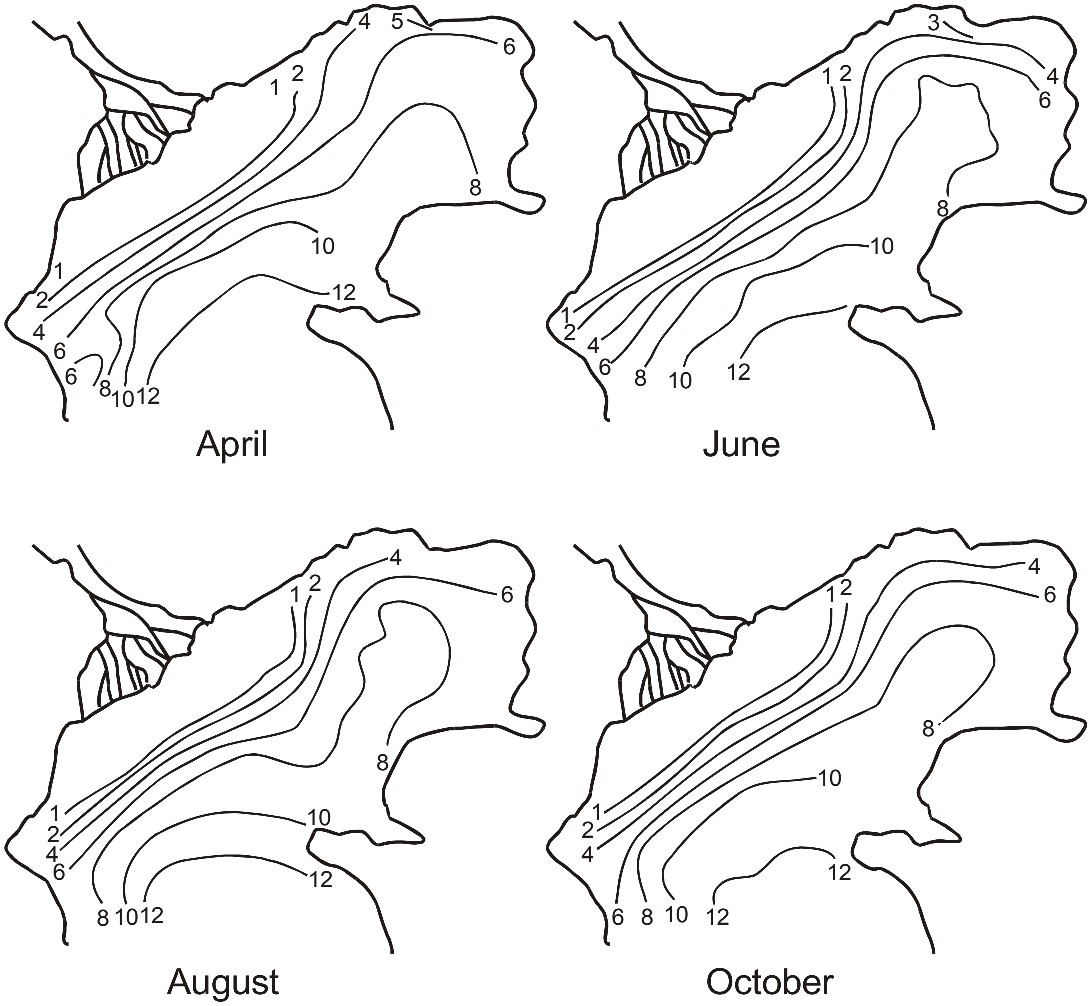

Figure 4. Mean salinity (g/l) in the Northern Caspian Sea. *(by Zenkevich, 1963)*

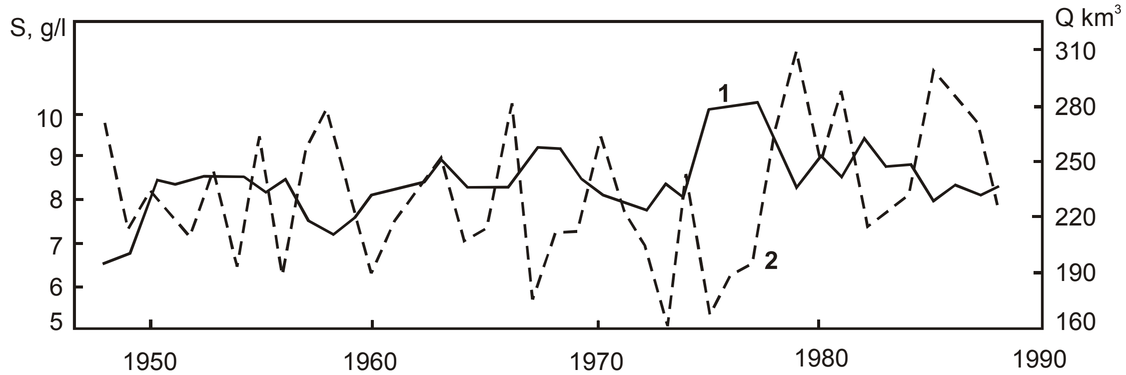

Figure 5. Long-term changes in the salinity of the Northern Caspian Sea (1) and the annual Volga run-off (2).
(by Kosarev, Yablonskaya, 1994)

The lowest concentration of salt is observed in the Northern Caspian. The average salinity of its waters is about 5-10 g/l. However, in certain areas of the Northern Caspian adjacent to the deltas of the rivers Volga, Ural and Terek, the water salinity is much lower than and fluctuates within 2-4 g/l. In the avant-deltas of these rivers, the water of the Northern Caspian can be consider as fresh, since its salinity is less than 0.5 g/l. In shoals of eastern coast of the Northern Caspian, the water salinity can be a little bit higher than the averages – 5-10 g/l. The point is that strong evaporation is observed in calm weather in the shallow gulfs of eastern coast, and, as a result, fast salinization up to 15-20 g/l occurs. Water salinity up to 30 g/l and even more can be observed in shallow gulfs of the Northern Caspian such as Mertviy Kultuk and Kaidak.

The salinity of the Middle Caspian is 12.7 g/l. This salinity is reduced only in the region of the delta of the Sulak River. As eastern coast of the Middle Caspian has no river runoff, the amount of rainfalls is very low, and the evaporation is high, so the water salinity in calm weather in surface coastal waters can reach 13.0-13.2 g/l.

The salinity of the Southern Caspian is 13 g/l. This salinity is lower in areas, adjacent to the regions of the deltas of the rivers Kura and Sefidrud, and also in the mouth of the river Atrek. Besides, higher salinity can be observed at eastern and southern coasts. The water salinity of 13.2-13.4 g/l is observed on shoals of the Turkmen coast.

The highest concentration of salt is observed in the gulf Kara-Bogaz-Gol. This gulf is a huge evaporator of the Caspian, and its water is brine. The salinity reaches 300-350 g/l and even higher. For this reason, the gulf Kara-Bogaz-Gol can be called a natural desalter of the Caspian Sea. Without this gulf, the present salinity of the Caspian would be much higher. A huge amount of mineral substances is accumulated at the bottom of Kara-Bogaz-Gola due to evaporation and natural sedimentation of salts.

The average salinity of the Caspian Sea is lower than that of the ocean approximately by a factor of three. However, the salinity of the Caspian waters is not the only difference from waters of the World Ocean, but also the salt composition (Table 3). The water of the Caspian Sea is rather poor with sodium and chlorine ions and is rich with ions of calcium and sulfates. The difference in the ratio of salts of Caspian and oceanic waters has arisen due to the isolation of the Caspian from the World Ocean. As a result, a gradual metamorphosis of Caspian waters under the influence of river runoffs took place.

Table 3. Average ionic composition of the World Ocean, Caspian Sea and Volga River

Ions	World Ocean (Lyman, Fleming, 1940)		Caspian Sea (Blinov, 1962)		Volga at Astrakhan (Bruyevich, 1938)	
	g/kg	% equ.	g/kg	% equ.	mg/kg	% equ.
Na^+	10.556	38.67	3.156	31.58	13.24	7.93
K^+	0.380	0.82	0.100	0.58		
Ca^{2+}	0.400	1.72	0.334	3.83	46.35	31.90
Mg^{2+}	1.272	8.79	0.740	14.00	8.88	10.17
Cl^-	18.980	45.07	5.347	34.69	10.86	4.20
Br^-	0.065	0.06	0.007	0.02		
SO_4^{2-}	2.649	4.64	3.038	14.55	50.92	14.48
CO_3^{2-}	0.071	0.23	0.100	0.73	68.31	31.32
H_3BO_3	0.026					
Total	34.399	100	12.822	99.98	198.56 (0.198g/kg)	100

In open parts of the sea, salinity increases with the depth (Fig. 6). So, for example, if on the surface of the Southern Caspian, the water salinity is 12.7 g/l, so at the bottom at the depth of 700 m, the water salinity reaches 13.1 g/l.

The temperature regime of the Caspian Sea is rather unusual (Fig. 7). On the one hand, it is characterized by considerable temperature differences in wintertime between its northern and southern areas, and on the other hand, leveling of the temperature regime between the Northern and Southern Caspian in summertime. In wintertime, in the north of the Caspian the average monthly air temperature makes -8-10°C while in the south air temperature remains about +10°C. In the winter only the Northern Caspian freezes. In this period, water temperature under ice can drop up to -0.5°C. In abnormally warm winters, the ice cover can be almost completely absent in the Northern Caspian. In summertime, the air temperatures of northern and southern parts of the sea are leveled. The average air temperature in the Northern Caspian is 24-25°C, only

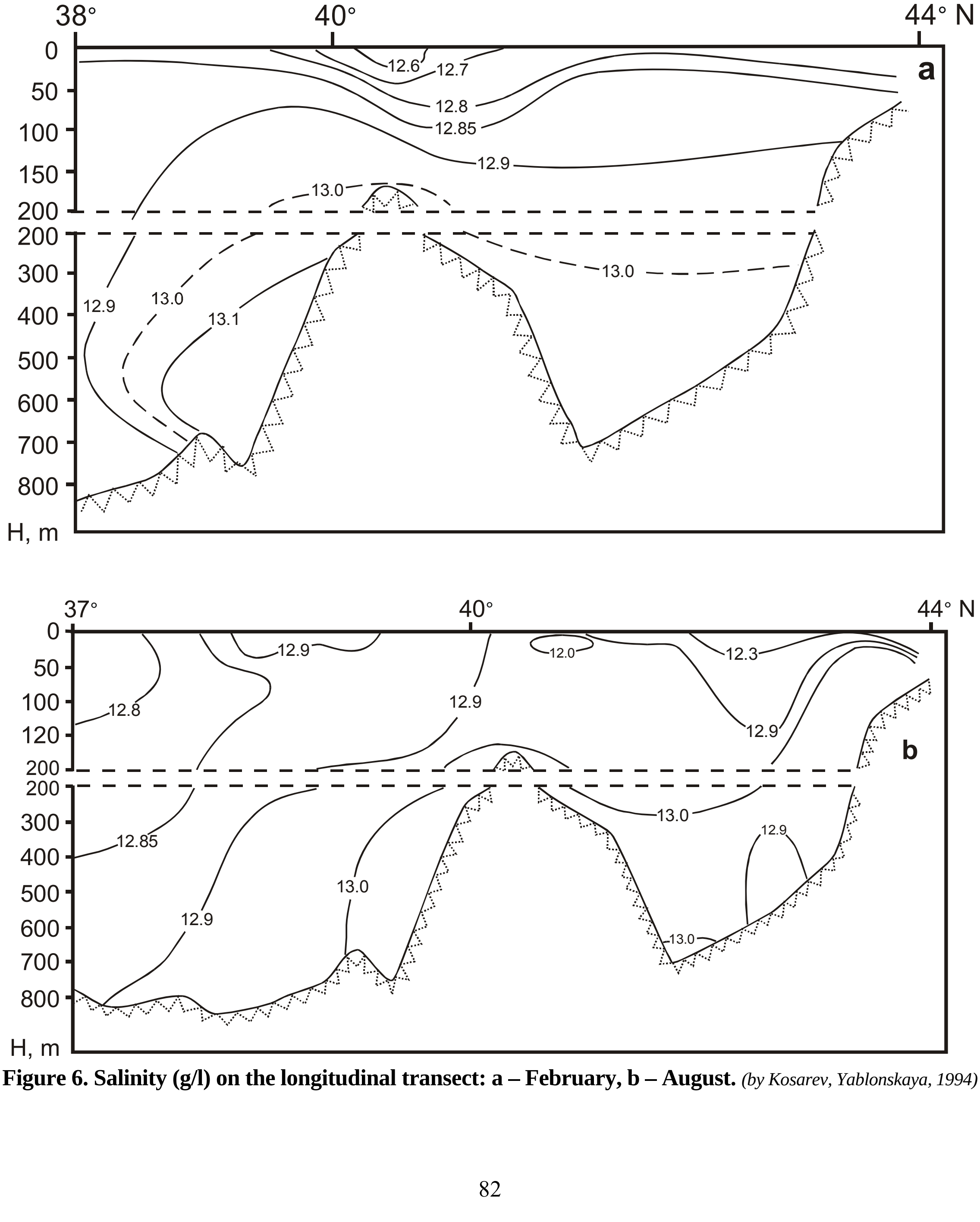

Figure 6. Salinity (g/l) on the longitudinal transect: a – February, b – August. *(by Kosarev, Yablonskaya, 1994)*

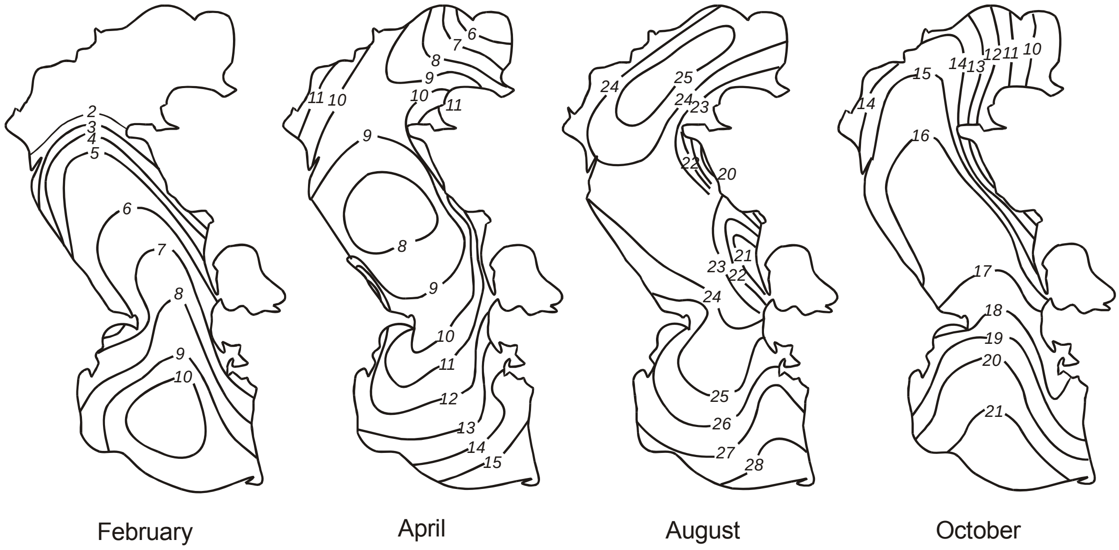

Figure 7. Mean temperature (˚C) on the surface in the Caspian Sea. *(by Zenkevich, 1963)*

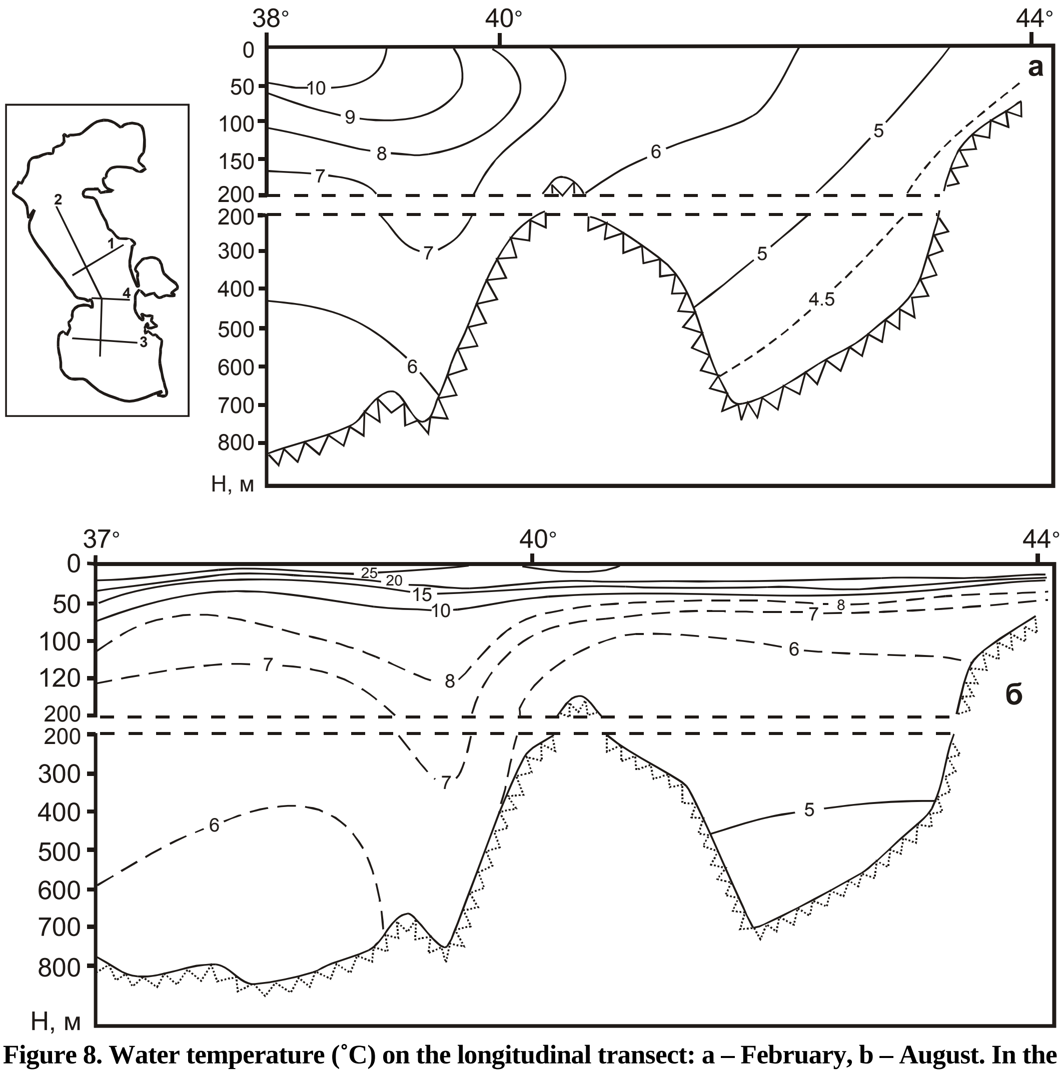

Figure 8. Water temperature (˚C) on the longitudinal transect: a – February, b – August. In the insert are shown the hydrological transects: 1 – Divichi – Kenderli, 2 – Zhiloi – Kuuli, 3 – Kurinsky Kamen – Ogurchinsky, 4 – longitudinal. *(by Kosarev, Yablonskaya, 1994)*

by 2-3 degrees higher than in the Southern Caspian. Water temperature in the Southern Caspian never drops below 13°C in wintertime, and in summertime it is usually increases up to 25°C and even 30°C. In the Middle Caspian in wintertime the average temperature of surface waters is only 6°C, and then it increases up to 25°C by the midst of a summer. In the Northern Caspian, seasonal changes of water temperature are maximal. In wintertime water temperature is about 0°C and even lower. In the middle of a summer, the average water temperature is 24°C. High summer water temperatures up to 40°C are observed at eastern shoals of the gulf Kara-Bogaz-Gol. Constant temperature is maintained at depths of the Caspian Sea both in winter and summer (Fig. 8). In the Southern Caspian at the depth below 150 m the water temperature is 7°C the whole year round, and at the depth below 500-600 m -6°C. In the Middle Caspian at the depths below 150 m, the temperature is about 6-5°C the whole year round, at the depth below than 400-500 m it ranges between 4.5 and 5°C. In the Northern Caspian there is no water stratification by temperatures due to its shallowness. Similar homotermia is observed in the shallow gulf of Kara-Bogaz-Gol. Thus, each of the four areas of the Caspian: Northern, Middle, Southern and the gulf Kara-Bogaz-Gol have its own certain features of the temperature regime.

There is a system of horizontal and vertical movements of water masses in the Caspian, as well as in any other water body. Surface currents in the Middle and Southern Caspian will form a rotating circulation. In the Northern Caspian the current regime is determined by river runoffs and prevailing winds. Here, especially in summertime, in shallow areas, strong winds and surges can completely change local currents. So, for example, surges can flood a coastal strand up to 30 km broad in lowland area lying between the delta of the Volga and the river Ural. The Caspian is a storm sea. From November to March of choppiness of the sea reaches force 6. The quietest period is the end of a spring and the first half of a summer.

Vertical movements of the Caspian waters are as well expressed as horizontal. Due to this the deep waters of the Caspian don't have a dead zone (oxygen deficiency causing deaths of hydrobionts) and are extremely rich with dissolved oxygen (Fig. 9). On the surface of the Caspian Sea in summer the amount of oxygen is close to saturation. In wintertime, oversaturation of up to 103-105% is observed all over the Caspian.

The waters of the Caspian Sea are characterized by high transparency (Fig. 10, 11). The most transparent are the open waters of the Southern Caspian. In the Middle Caspian the transparency of open waters is a little bit lower. In the Northern Caspian, because of large inflow of rivers the transparency is low.

The trophic level and primary production of the Caspian Sea is low. Majority of nutrients brought in the Caspian with waters of the tributaries and, first of all, the Volga. Huge extents of the deltas are covered with macrophyte thickets. These macrophytes detain nutrients running into the Caspian. Levels of nutrients in the Caspian Sea are low, even in the Northern Caspian, which is the most productive and rich part of the sea. Eutrophic conditions are observed only in some regions adjacent to the delta of the Volga. Levels of nutrients in the Middle and Southern Caspian are very low. In these parts of the Caspian Sea the nutrients arrive at the expense of an internal recirculation and with small runoff of rivers and also with rains. Thus, it is incorrect to name the Caspian a rich lake with high productiveness. The Caspian Sea is a poor lake in terms of production, only the Northern Caspian is not so poor.

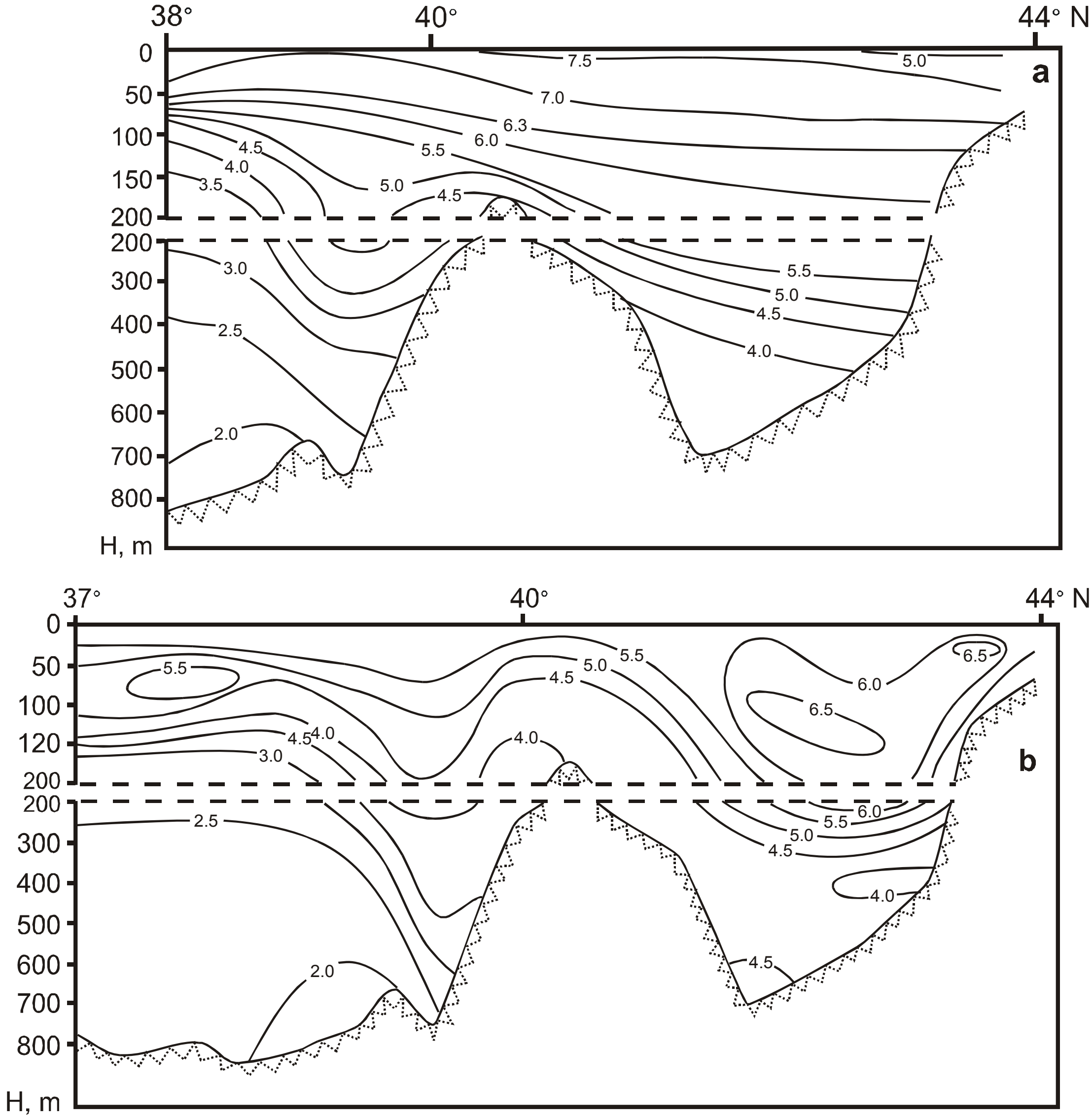

Figure 9. Distribution of dissolved oxygen (ml/l) at the longitudinal transect: a – in February, b – in Augus.t *(by Kosarev, Yablonskaya, 1994)*

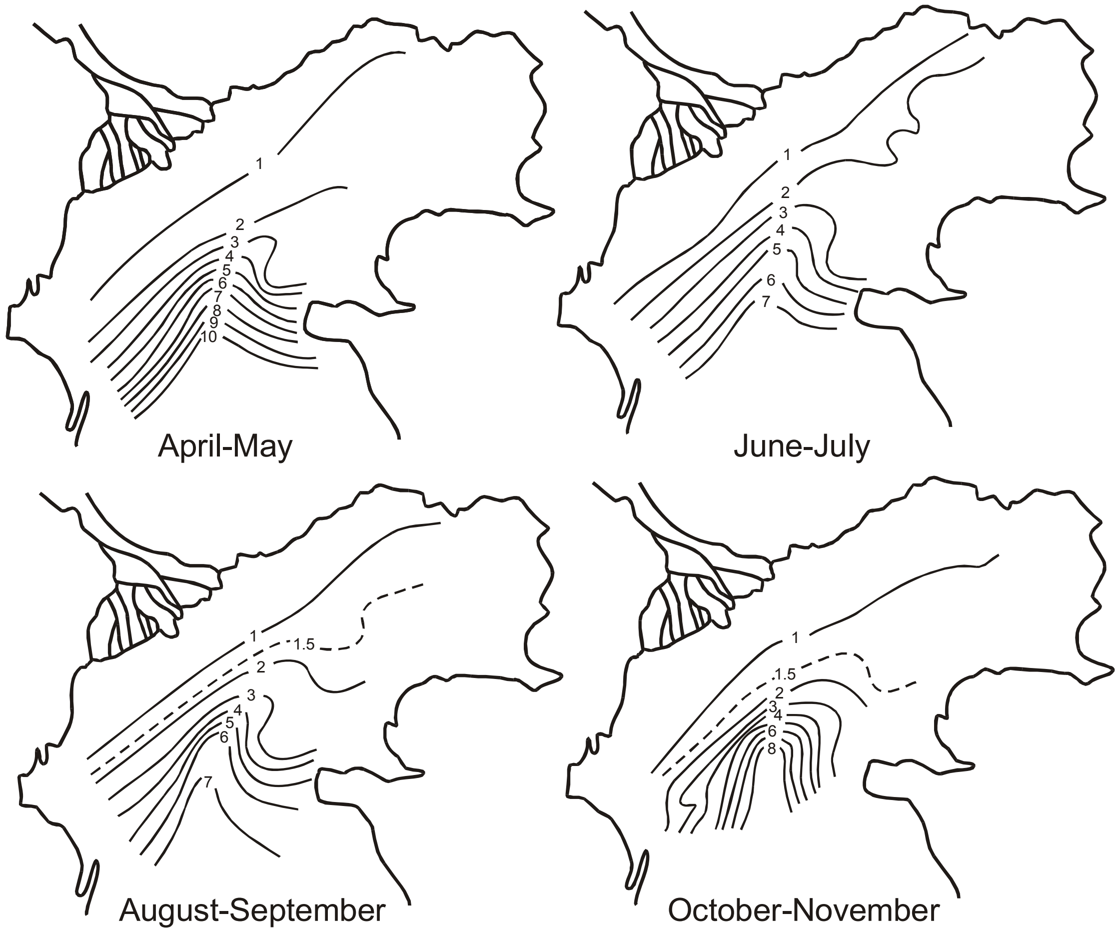

Figure 10. Transparency of the water (m) in the Northern Caspian Sea. *(by Zenkevich, 1963)*

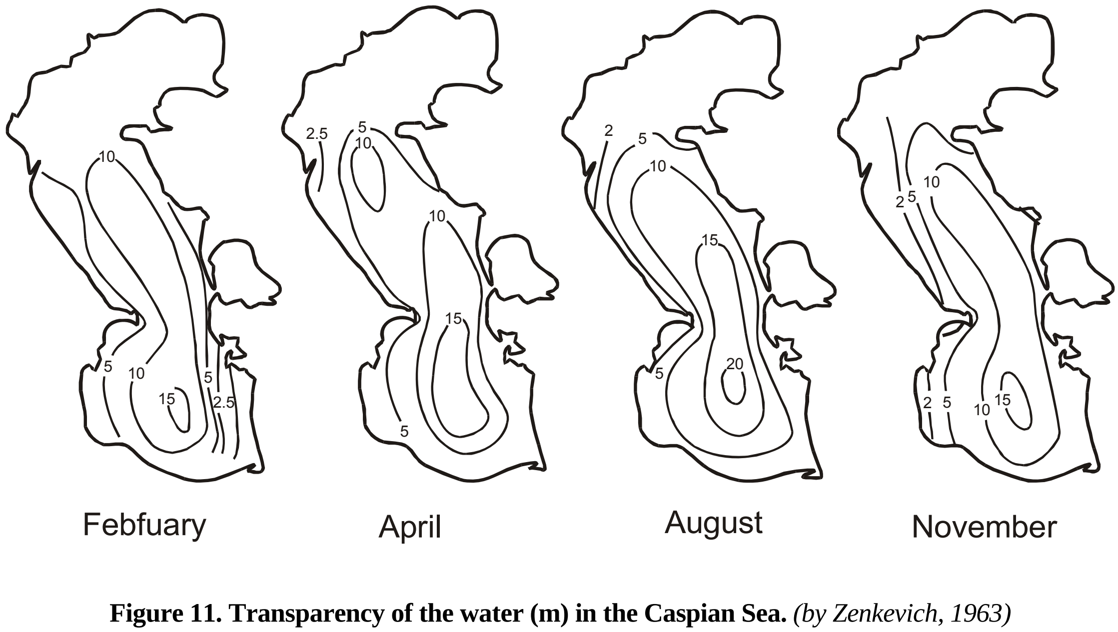

Figure 11. Transparency of the water (m) in the Caspian Sea. *(by Zenkevich, 1963)*

Main species groups in the Caspian Sea

Because the Caspian Sea is largest lake in the world one can assume that it has the highest biodiversity. It is logical to assume that the more is the area of a lake, the more plant and animal organisms live in it. In our opinion this correlation with the area is rather indirect. Certainly, the more is the area of a water body, the more is the probability that it will contain more species of hydrobionts. However, there are no doubts that, in this case, the defining parameters are the age a lake, its biotope diversity, biotic and abiotic conditions, availability of necessary and balanced amount of matters and energy.

An important feature of the Caspian is the extreme diversity of biotopes, biotic and abiotic conditions (Zenkevich, 1963). First of all, water salinity in different parts of this lake is quite different (Kosarev and Tuzhilkin, 1995). Variable salinity conditions strongly increase the biodiversity. Due to this, freshwater, brackish, euryhaline and hyperhaline hydrobionts can inhabit the Caspian, and due to proximity of chemical compositions of marine and Caspian waters many marine organisms will perfect feel themselves here. It is especially necessary to note that actually three ecosystems coexist in parallel within the borders of the Caspian: freshwater, brackish and hyperhaline and it promotes biological diversification of this lake.

The vertical stratification of water salinity in the modern Caspian is poorly expressed and the water salinity of the sea floor hardly differs from that on the surface. However, earlier, when the level of the Caspian was much higher than now, and there was strong vertical stratification of bottom salinity, the oxygen was practically absent at the bottom (Kosarev and Tuzhilkin, 1995; Dumont, 1998). That is why, nowadays, there is poor life at the depths of more than 100 m. At present there is no abyssal fauna and flora in this lake. Probably, modern animals and plants "genetically remember" the recent disastrous cases of deep oxygen depletion. It is possible to assume that this ancient natural ecological catastrophe heavily reduced modern diversity of the Caspian fauna and flora.

The temperature parameters are also extremely diverse and it also contributes to the Caspian biodiversification. Latitudinal stratification of surface water temperatures allows both cold water, and warm water hydrobionts to live in this lake. Besides, there is strong vertical temperature stratification in the Caspian. Below the zone of a temperature jump, the water temperature remains low even during the hottest summer months. The presence deep cold water in the Caspian allows populating its upper horizons even with arctic organisms (Zenkevich, 1963; Kosarev and Yablonskaya, 1996). The diversity of temperature conditions of the Caspian increases its biodiversity. It is possible to state that there are three types of water bodies within the Caspian: cold, moderate and warm.

Production characteristics of various areas of the Caspian are also quite different and, as well as in case of salinity and temperature, this results in magnification of biodiversity of this lake.

The modern fauna and flora of the present Caspian Sea consists of the four main components: 1 – of Caspian origins; 2 – of arctic origins; 3 – of Atlantic and Mediterranean origins; 4 – of freshwater origins (Derzhavin, 1912; Knipovich, 1938; Berg, 1928; Zenkevich, 1963).

In Zenkevich’s opinion (1963), the fauna and flora of the Caspian Sea usually could not compete with invaders and often such invaded fauna and flora destroyed native species.

The biodiversity of the Caspian Sea is 2.5 times poorer, than that of the Black sea (Table 4), or 5 times poorer, than that of the Barents Sea (Zenkevich, 1963). The main reason of this is probably its variable salinity. For the present freshwater fauna and flora, the water salinity is too high, and for the present marine species is low. Thus, the modern Caspian Sea is a real paradise for brackish water species originating both from marine, and from continental water bodies (Birstein, 1939; Mordukhai-Boltovskoy, 1979). However, in our opinion, the comparison with purely freshwater lakes shows that unstable salinity of the Caspian is more favorable for diversification than for loss of biodiversity.

Table 4. Faunal Composition of Free-Living Metazoa of the Black, Azov and Caspian Seas (by Atlas …, 1968; Mordukhai-Boltovskoi, 1972, 1978).

Groups	Number of species	
	Black and Azov Seas	Caspian Sea
Porifera	28	1
Hydrozoa	28	5
Scyphozoa	3	–
Anthozoa	4	–
Ctenophora	1	–
Turbellaria	103	25
Nemertini	33	1
Nematodes	141	52*
Gordiacea	1	–
Rotatoria	102	32
Gastrotricha	23	–
Kinorhyncha	10	–
Polychaeta	192	7
Oligochaeta	33	22
Hirudinea	10	3
Sipunculida	1	–
Bryozoa	20	6
Kamptozoa	2	1
Phoronidea	1	–
Loricata	2	–
Bivalvia	90	25
Gastropoda	113	82
Scaphopoda	1	–
Branchiopoda	17	30
Ostracoda	111	27
Copepoda	184	16
Cirripedia	5	2
Amphipoda	108	72
Isopoda	29	2
Tanaidacea	6	–
Mysidacea	19	20
Cumacea	24	18
Decapoda	37	5
Acarina	27	2
Pantopoda	8	–
Insecta	13	8
Tardigrada	5	–
Asteroidea	1	–
Ophiuroidea	4	–
Echinoidea	1	–
Holothurioidea	8	–
Chaetognatha	2	–
Ascidiacea	8	–

Groups	Number of species	
	Black and Azov Seas	Caspian Sea
Appendicularia	1	–
Acrania	1	–
Cyclostomata	1	1
Pisces	161	76
Reptilia	2	–
Mammalia	4	1
Total	1729	542

* – by A.V. Chesunov (1978)

The phytoplankton of the Northern Caspian is different from that of the Middle and Southern Caspian with typical features of estuarine plankton, impoverished by marine elements (Proshkina-Lavrenko and Makarova, 1968). The phytoplankton of the Northern Caspian in 1986-1994 consisted of 230 species, the Middle and Southern – 82 and 83 species, correspondingly. According to data of the latest reports specific composition of plankton microalgae only of the Northern Caspian (Hydrometeorology …, 1996) includes more than 400 species. However, despite of this diversity, only a few species are predominating. In relation to salinity, algae are subdivided into 5 ecological groups: freshwater, brackish and brackish-freshwater species, and a small number of marine species and halophobes (Levshakova, 1971). Of freshwater algae, the green algae are on the first place by the number of species. Blue-green algae consist of freshwater and brackish-freshwater species. There are also marine and brackish forms, but their role is insignificant.

Diatoms are widespread all over the Caspian and are equally diverse in all ecological groups. They take a leading place by number of species. A large marine diatom *Rhizosolenia calcar-avis* takes the leading place by biomass. Perydine algae are represented by mainly marine and brackish water forms. The specific diversity decreases southward due to shedding of freshwater forms.

The species composition of periphyton of the Caspian amounts to some 200 species of algae.

In the Caspian Sea there are known 87 species of macrophytes relating to 5 types, 8 classes, 17 orders, 24 families and 45 genera. The core of the Caspian algoflora is the green alga. Southern reed *Phragmites australis* and narrow-leaved cat's tail *Typha angustifolia* are dominants in communities of the transient zone Absolute dominants of communities of seawaters are *Zostera minor*, *Myriophyllum spicatum* and *Ceratophyllum demersum*. Only 5 species of higher water plants are known in eastern part of the Caspian Sea. All of them belong to flowering plants: *Z. minor, Potamogeton pectinatus, Ruppia spiralis*, *R. maritima* and *Najas marina*.

In the Caspian Sea fauna 4 main zoogeographic groups of animals are distinguished – freshwater, Arctic, Mediterranean-Atlantic and autochthonous. This fauna is mostly eurythermal and euryhaline. Representative features of the Caspian Sea fauna are:

- It is poor in the number of species but diverse in origins;
- It is highly endemic (46% of species are Caspian endemics);
- Species of autochthonous Caspian complex are predominating in the benthic fauna;
- A vigorous process of speciation is typical for it (Kasymov, 1987, 1994).

Fishes and crustaceans have the greatest diversity in the Caspian (Fig. 12, 13; Table 5). They come to 63% of the total number of species. These organisms, due to very good osmoregulatory abilities, can live in a very broad range of salinity: from fresh water up to brackish, and even in more salty water, than oceanic (Zenkevich, 1963).

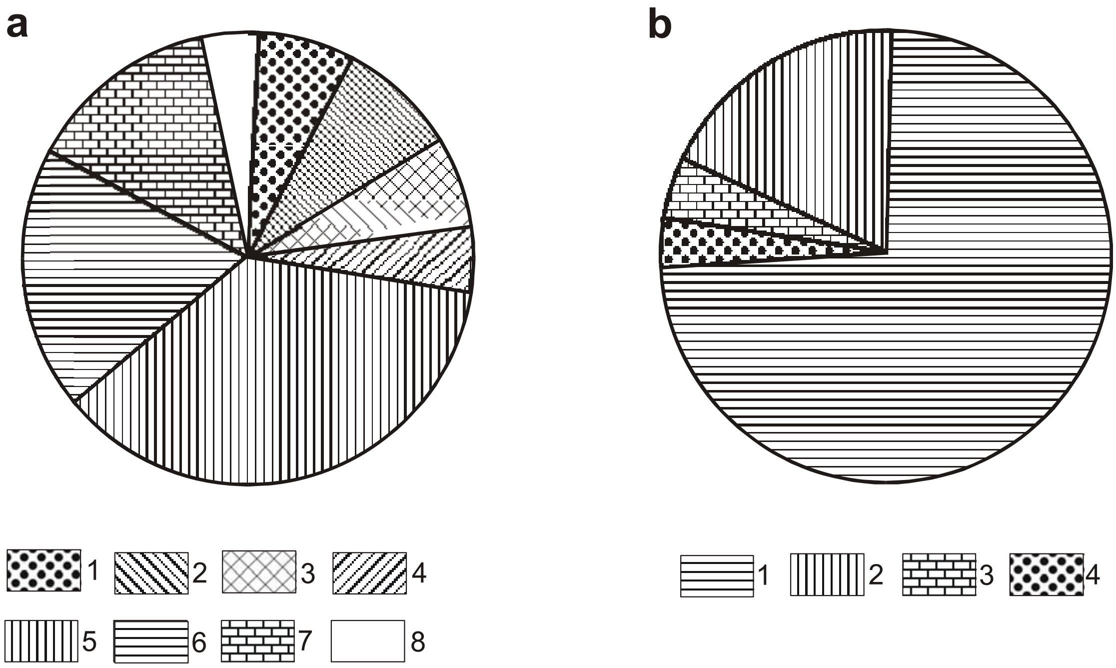

Figure 12. Faunal composition of free-living Metazoa of the Caspian Sea, %. (by Atlas …, 1968; Mordukhai-Boltovskoi, 1960, 1978).

a – In systematic groups: 1. Turbellaria, 2. Nematodes, 3. Rotatoria, 4. Annelida, 5. Crustacea, 6. Mollusca, 7. Pisces & Cyclostomata, 8. others.

b – In faunal complexes: 1.Autochthonous, 2. Freshwater, 3. Mediterranean, 4. Arctic.

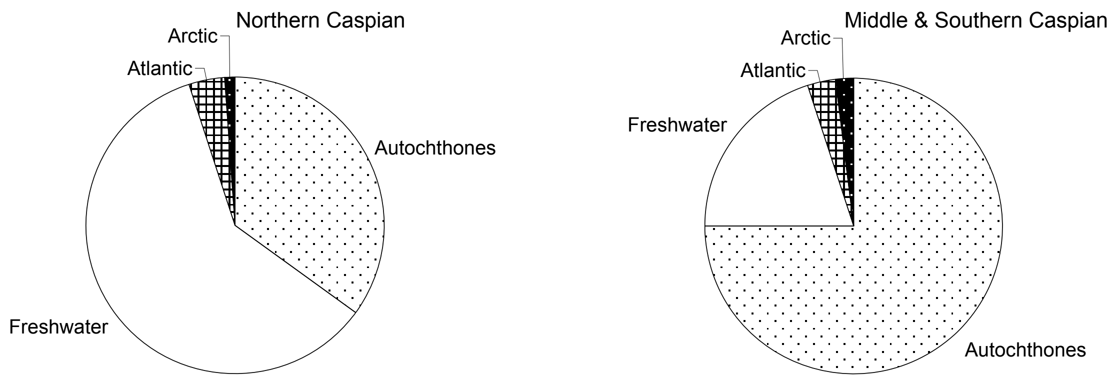

Figure 13. Faunal composition of free-living Metazoa in the Northern Caspian and in the Middle and Southern Caspian in faunal complexes.

The prevalence of these two groups of animals in the present Caspian proves that in past the salinity in this lake used swing, and only species with very good osmoregulatory abilities could survive and to provide good speciation and adaptive radiation. In past, species with insufficient osmoregulation died out because of changes in water salinity or because their speciation and adaptive radiation were suppressed or decreased owing to negative influence of varying salinity. Thus, the modern biodiversity of the Caspian Sea simply reflects a complicated history of Paleo-Caspian transgressions and regressions, desalinisation and salinization.

The first good report on the Caspian Sea fauna and flora was published in 1963 by L. Zenkevich. However, this scientist used a lot of data previously published in 1951 by A. Derzhavin. According to data to two authors, 718 species inhabit the Caspian: 62 species of protozoa, 397 - invertebrates, 79 - vertebrates and 170 species of parasitic organisms. So, without protozoa and parasitic organisms, A. Derzhavin and L. Zenkevich distinguished only 476 species of free living Metazoa. Of these species, some 46 % are endemics of the Caspian Sea, 66 % inhabit also in adjacent southern seas, 4.4 % are of Atlantic and Mediterranean origins and 3 % – of Arctic origins.

315 species and subspecies are registered in zooplankton of the Caspian Sea (Kasymov, 1987, 1994); of these 135 species refer to infusorians (Agamaliyev and Bagirov, 1975). The main part of zooplankton is species of Caspian origins.

Table 5. The Caspian Sea ichthyofauna composition (by Kosarev, Yablonskaya, 1994).

Family	Total number of species and subspecies	Faunistic complexes			
		Autochthones	Mediterranean	Arctic	Freshwater
Petromizonidae – lampray	1	1			
Acipenseridae – sturgeon	7				7
Clupeidae – shad	18	18			
Salmonidae – salmon	3			2	1
Esocidae – pike	1				1
Cyprinidae – carp	42	5			37
Cottidae – loach	5	1			4
Siluridae – wels	1				1
Gadidae – burbot	1				1
Gasterosteidae – stickleback	1	1			
Anguillidae – eel	1				
Syngnathidae – needle-fish	1		1		
Poeciliidae – gambusia	1				1
Mugilidae – mullet	2		2		
Atherinidae – atherine	1		1		
Percidae – perch	5	2			3
Gobiidae – goby	35	35			
TOTAL	126	63	5	2	56

The species composition of zooplankton of the Northern Caspian amounts to about 200 species. Infusoria are represented most diversely (more than 70 species). Rotatoria (> 50), Cladocera (> 30) and Copepoda (> 20) are less diversely represented (Kasymov, 1997). Only 30-40 species are found quite regularly. Meroplankton, represented mainly by larvae of bivalves and crustaceans, contributes to biodiversity of plankton communities during reproduction. Changes of complexes of organisms, from brackish to euryhaline and marine, are observed from northern to the south.

In the 1970s, under low sea levels and increased salinity, *Eurytemora minor, Polyphemus exiguus*, species of *Apagis* and *Cercopagis*, arctic invader *Limnocalanus grimaldii* are widely distributed, especially, in deepwater areas. Mediterranean euryhaline and eurythermal species such as *Calanipeda aquaedulcis* and *Pleopis (Podon) polyphemoides* dwelled everywhere but concentrated in coast areas. A freshwater complex – rotifers and cladocerans, occupied shallow and estuaries with fresher water: species of *Brachionus*, *Moina*, *Diaphanosoma* and *Bosmina*.

Representative species of zooplankton in coastal shallow zone of the Middle and Southern Caspian are: *Calanipeda aquaedulcis, Acartia clausi, Heterocope caspia, Podonevadne camptonux,* and *P. angusta*. The presence of larvae of benthic organisms in mass is representative of vernal and summer plankton of coastal zone. Both in the Middle and Southern Caspian, more than 50 % of the total biomass of plankton is formed by the larvae of *Balanus* in spring, and by the larvae of Mollusca in summer (Bagirov, 1989).

Eurytemora grimmi, E. minor, Limnocalanus grimaldii and opossum shrimps *Mysis caspia, M. macrolepis, Paramysis baeri* are dominating species of the central holistic zone.

The transient zone has a mixed composition of population; species of both shallow and central holistic zone are found here. By biomass, *Eurytemora grimmi* and *E. minor* dominate here.

At western coast of the Middle and Southern Caspian, cladocerans (Cladocera) are dominating by the number of species of zooplankton. Of copepods, the dominating species are *Eurytemora grimmi, E. minor, Acartia clausi, Calanipeda aquaedulcis,* and *Limnocalanus grimaldii*. Of cladocerans, *Podon polyphemoides, Podonevadne trigona*, *Camptonyx macronyx, P. camptonyx podonoides, Evadne anonyx producta, E. anonyx deflexa* etc. are found here.

A stable trend of increasing of numbers of species of freshwater complex (with 54 up to 62 %) is observed in zooplankton of the Northern Caspian in the modern period due to increased discharge of the Volga, rise of sea levels and expansion of its area. Mainly, the rotifer-cladoceran plankton predominated.

68 species and varieties were discovered in zooplankton of eastern part of the Northern Caspian. The most diversified group – rotifers were represented by freshwater forms (more than 80 %), living in estuarine areas of the Ural, and only 2 marine species - *Synchaeta cecilia* and the endemic *T. caspica*. Euryhaline and eurythermal forms of *S. stylata* and heat-loving *Brachionus quadridentatus*, *Keratella tropica* are widespread, *Filinia longiseta limnetica* is less widespread. *Asplanchna priodonta* and *Brachionus plicatilis* are typical for warm seasons, and *S. cecilia* - for cold periods.

Of cladocerans, a marine crustacean, brought in by water current from the Middle Caspian, *Pleopis polyphemoides* was a background species in spring, *Podonevadne* was constantly present in summertime. The endemic *Cornigerius maeoticus hircus* is less widespread, *C. maximowitschi* and *C. bicornis* are absolutely rare. The Ponto-Aral-Caspian endemic *Evadne anonyx* avoids shallow areas with fresher water. The other representatives of cladocerans are freshwater crustaceans of family Chydoridae and *Bosmina longirostris*.

The group of mass copepods – *Calanipeda aquaedulcis* and *Halicyclops sarsii* was supplemented in the 1990s with *Acartia clausi*. The facultative plankters Harpacticoida was found everywhere, particularly, the endemic *E. concinnum*. *H. caspia* lowered considerably. *E. minor* and *Limnocalanus grimaldii* are rarely found. Remaining copepods refer to freshwater species of coastal regions.

With the increase of sea levels, the number of freshwater species in zooplankton (from 54 up to 62%) has increased. Rotifer plankton with an increase of the share of freshwater and brackish water complexes was predominating.

The biological seasonal prevalence in zooplankton is determined not only with temperature changes, but also with changes of salinity. In spring after destruction of the ice cover and prior to entering into the sea of freshet waters, euryhaline and marine copepods dominate in plankton.

In May, with increase of water temperatures, freshwater Cladocera and Rotatoria begin to develop reaching the maximum biomass in summer. A freshwater complex of organisms develops in a zone where fresh and marine waters are mixing and reveals in western part of a competitive area. Euryhaline copepods, mainly, adults, take a leading position in plankton in October.

A trend of growth of species diversity of zooplankton occurs in the Middle and Southern Caspian. It has been supplemented with a new species *Acartia clausi* for Caspian, which becomes a dominant in certain seasons. An increase of species composition of zooplankton in the 1990s has taken place at the expense of undefined species from Harpacticoida and Cyclopoida, and also freshwater forms.

It seems that an increase of species diversity of zooplankton also at western coast of the Middle and Southern Caspian, along with favorable hydro-meteorological conditions, is also linked to a decrease of anthropogenic pollution and an increase of sea levels.

The most typical feature of the benthic fauna is the predominance of autochthonous Caspian species, which often are endemic for the Caspian and are grouped into endemic genera or sub-genera. Caspian endemics and remnants of the fauna of Tertiary seas, which existed about 5-6 million years ago, refer to them: mollusks *Dreissena*; *Micromelaniidae*, *Pyrgula*; polychaete (Polychaeta) except for newcomers; a part of oligochaetes (Oligochaeta), leeches (Hirudinea); decapods (Decapoda), except for shrimps (Palaemonidae) and crabs (*Rhithropanopeus harrisii*); some species of turbellarians (Turbellaria); Cumacea; a large part opossum shrimps (Mysidacea) and scuds (Amphipoda); sponges (Demospongiae); pearlweed (Bryozoa) etc. (Dumont, 2000).

The second group consists of generative-freshwater species, which invaded the Caspian during its desalinization and adapted to live in brackish water. This fauna is rather poor and is represented by separate species of larvae of chironomids (Chironomidae), oligochaetes (Oligochaeta), freshwater mollusks – *Dreissena*, and among microfauna – of some species of turbellarians (Turbellaria), ostracods (Ostracoda) and benthic rotifers (Rotatoria) (Kasymov, 1987, 1994).

The third group consists of arctic species, which invaded the Caspian from northern seas in later glacial period, about 10-12 thousand years ago and nowadays are widespread in northern seas. These are some species of polychaetes (Polychaeta), part of opossum shrimps (Mysidacea) and scuds (Amphipoda).

The fourth group is made of Mediterranean species, which invaded the Caspian from Azov-Black Sea basin independently or were introduced by people. These include: mollusks – *Mytilaster, Cerastoderma, Abra*, polyhaetes – *Nereis*, crustaceans – shrimp (Palaemonidae), crab (*Rhithropanopeus harrisii*), barnacles (*Balanus*), 2 species of pearlweeds (Bryozoa), etc. (Agamaliyev, 1983; Kasymov, 1987, 1994).

The main part of benthic organisms lives on or in the seafloor (epi- and endobenthos). These are usual representatives of periphyton (fouling) – sponges (Demospongiae), pearlweed (Bryozoa), worms, barnacles (Cirripedia), bivalves (Bivalvia), *Mytilaster, Dreissena*, infusorians (Infusoria), and also nektobenthos (Palaemonidae, Mysidacea) and planktobenthos (Copepoda, Cladocera and Rotatoria).

Factors defining geographical distribution of benthic animals include:

- Salinity (especially for the Northern Caspian).
- Ground and related gas regime of benthic layer.
- Distribution and population of the major benthos consumers – benthos eating fishes.

In regards to salinity, 4 ecological groups are distinguished in the benthos of the Caspian Sea:

1. Freshwater forms: freshwater gastropods (Gastropoda) and bivalves (Bivalvia), oligochaetes (Oligochaeta), larvae of chironomids (Chironomidae), spreading within estuaries with the salinity of 0-2 g/l.

2. The 2nd group is more diverse. It includes coastal and brackish forms, including freshwater by origin invertebrates (Oligochaeta, Bryozoa, larvae of Chironomidae) and representatives of autochthonous Caspian fauna (higher crustaceans, ampharetids – Ampharetidae, mollusks – *Hypanis vitrea*, *Dreissena polymorpha polymorpha*, crustacean *Pterocuma sowinskyi*). These forms live mainly under the salinity ranging from 0-2 up to 7 g/l; some of them (higher crustaceans) are euryhaline and can live in a wide range of salinity and depths (Romanova, 1958, 1959).

3. Benthos of the 3rd group is more diverse. It includes brackish forms, living under salinity from 3-5 to 10-11 g/l. A mass development of relict Caspian mollusks is typical for this group, which habitat is limited to northern part of the Caspian Sea (*Didacna trigonoides*, *Hypanis angusticostata*, *Dreissena polymorpha andrusovi*, and also Amphipoda and Cumacea).

4. Marine forms are the most diverse. This group includes invertebrates of Mediterranean origin: *Cerastoderma lamarcki*, *Mytilaster lineatus*, *Abra ovata*, *Hediste diversicolor*, *Balanus improvisus*, *Rhithropanopeus harrisii* and salt-loving forms of relict Caspian faunal complex (inhabits mainly in the Middle and Southern Caspian: *Didacna barbotdemarnyi, D. longipes, Dreissena rostriformis*). Mass development of marine forms is observed under the salinity of above 8-10 g/l.

An increase of Caspian level and desalinization of its waters have made changes into a qualitative composition and quantitative parameters of hydrobionts. In all regions of the sea, the significance of organisms of freshwater and brackish water complexes has increased. Replacement of salt-loving organisms happened in benthos of the Northern Caspian, and in the Middle and Southern Caspian, the greatest development of benthic invertebrates was observed during the spell of increased discharge of the Volga.

Of the total number of species marked in foulings of the Caspian Seas, only 8-10 play an essential role in shaping fouling. These are *Balanus improvisus, B. eburneus, Mytilaster lineatus, Cordylophora caspia, Perigonimus megas, Conopeum seurati* and *Rhithropanopeus harrisii tridentata*. Purely Caspian fouling fauna is qualitatively poor and amounts only to five animal species – *Dreissena polymorpha, D. elata, Cordylophora caspia, Corophium curvispinum, C. robustum*. An essential part of foulers are exotic species.

Endemic fauna is the richest and most diverse (Dumont, 2000). It is represented by: 4 species of Spongia, 2 species of Coelenterata, 29 species of Turbellaria, 3 species of Nematodes, 2 species of Rotatoria, 2 species of Oligochaeta, 4 species of Polychaeta, 19 species of Cladocera, 3 species of Ostracoda, 23 species of Copepoda, 20 species of Mysidacea, 1 species of Isopoda, 68 species of Amphipoda, 19 species of

Cumacea, 1 species of Decapoda, 2 species of Hydracarina, 53 species of Mollusca, 54 species of fishes, and 1 species of mammals.

The large number of species is of freshwater origins. Such species constituted the biggest part of such groups as Rotatoria, Cladocera, Copepoda and Insecta.

By A. Derzhaviny's (1951) and L. Zenkevichy's (1963) opinion, ichthyofauna used to consist of 78 species. The family Petromyzonidae had 1 species, Acipenseridae 5, Clupeidae 9, Salmonidae 2, Esocidae l, Cyprinidae 15, Cobitidae 2, Siluridae l, Gadida 1, Gasterosteidae l, Syngnathidae1, Atherinidae 1, Percidae 4, Gobiidae 30, Mugilidae 2, Pleuronectidae 1, Poeciliidae 1 species. According to fresher data of Y. Kazancheyev (1981), the total ichthyofauna of the Caspian Sea amounts to 123 species (76 species and 47 subspecies), referring to 17 families and 53 genera. In comparison with other southern seas (Azov, Black, Mediterranean), the ichthyofauna of the Caspian Sea is extremely poor and consists of representatives of autochthonous (63 species and subspecies), Mediterranean (5), arctic (2) and freshwater (56) complexes. Some species have populated the Caspian as a result of human activities.

The distinctive feature of the Caspian ichthyofauna is its high endemism, observed from the category of a genus up to the level of a subspecies. Early separation of the Caspian Sea from the World Ocean has ensured a high level of endemism of its ichthyofauna. According to Y. Kazancheyev (1981), the number of endemics at the level of genus makes 8.2 %, at species level – 43.6 %, at subspecies level – 100%. The greatest number of endemic forms belongs to Clupeidae and Gobiidae, though they occur also in other systematic groups. In general, the Caspian is inhabited by 4 endemic genera, 31 endemic species and 45 endemic subspecies. This has allowed L.S. Berg to single out the Caspian into a special ichthyo-geographic subregion (Kazancheyev, 1981). The active speciation processes in the Caspian Sea are largely related to special hydrological conditions in geological past and present. Repeated transgressions of the sea, its salinization and desalinization promoted formation of new species and subspecies and as well as various biological and ecological forms and races.

One of the endemic species of Caspian Sea fauna seal *Phoca caspica*, the smallest existing varieties of seals and the nearest relative of northern earless seals *Puso*. It is the only mammal in the fauna of the Caspian Sea. This seal ranges almost in all parts of the sea, periodically visiting deltas of the rivers Volga and Ural (Badamshin, 1966, 1969). Considerable concentrations of seals occur on shell islands in eastern part of the Northern Caspian and on sandy spits of the Southern Caspian in autumnal period (October - November) (Krylov, 1982, 1986). The greatest concentration of seals is observed on the ice cover in the Northern Caspian during reproduction and molting in wintertime (Mammals of Kazakhstan, 1981). The magnitude of the population of the Caspian seal has dwindled from approximately 1.5 million animals in the beginning of the 20^{th} century up to 360-400 thousand animals in the end of the 1980s (Krylov, 1989, 1990).

In compliance with A. Derzhavin (1951) and L. Zenkevich (1963), the crustaceans used to include 114 autochthonous species. The biodiversity of molluscs is also great. From 57 up to 70 autochthonous species are registered in the Caspian Sea.

According to data published by A. Chesunov (1978), the number of species of free living Metazoa in the Caspian Sea is more than 542 and not 476.

The real biodiversity of the Caspian Sea both of plants and of animals is not known today. There are still many new species and subspecies, waiting of description.

Many present marine animals like Scyphozoa, Anthozoa, Ctenophora, Gordiacea, Gastrotricha, Kinorhyncha, Sipunculida, Phoronidea, Loricata, Scaphopoda, Tanaidacea, Pantopoda, Tardigrada, Asteroidea, Ophiuroidea, Echinoidea, Holothurioidea, Chaetognatha, Ascidiacea, Appendicularia and

Acrania are not known in the Caspian. But some of these organisms, which are capable of osmoregulation and which are the most euryhaline, can invade into the Caspian.

There are a lot of freshwater and brackish water species ranging in estuaries of Caspian tributaries. L. Zenkevich included approximately 450 species in his list of free living Metazoa in 1963, A. Chesunov included approximately 550 species in 1978, and A. Kasymov included approximately 950 species in 1987. It is possible to imagine that the real number of free living Metazoa is approximately 1500 or even 2000 species. Speciation in the Caspian Sea has created a general high level endemism (approximately 42-46 %) which is a little bit lower, than in Baikal. The smaller number of endemics in the Caspian is, probably, related to loss of the Caspian deep-water fauna. But it is possible, that after conducting special researches, the number of endemic species in the Caspian can increase. In our opinion, deep-water oxygen depletions during transgressions of the ancient Caspian sharply reduced the number of Caspian endemics. Only in the Caspian, some groups of animals, which were subject to significant adaptive radiation, had a level endemism close to 100%. If Caspian deep-water endemics had survived, then today the biodiversity of the Caspian would be the greatest in the world for continental water bodies.

Commercial species

The bioresources of the Caspian Sea are of high economic value. Many species of fishes, crawfishes, shrimps, seal certain waterfowls, some wild animals, living in the coastal zone are used for commercial purposes. Each region has own species composition of used animals.

Fisheries are an important activity in coastal regions of all Caspian littoral countries (Table 6) (Ivanov, 2000; Ivanov, Sokolskiy, 2000). In the recent past, some 500-600 thousands tons of fishes used to be annually landed, and the main part of yields used to constitute such valuable fish species, as Beluga, Russian sturgeon, stellate sturgeon, sterlet, Caspian inconnu, anadromous and marine herring, zander, Caspian bream, carp, Caspian roach, catfish, asp common, kutum, etc. Such a position remained to the beginning of the 1950s, when hydroconstruction, yearly redistribution of river runoffs, restriction of vernal discharges, withdrawal a great amount of water for irrigation and other economic needs, exploitation of watersheds without effective means of fish protection, and water pollution have led to deterioration of conditions of reproduction of valuable fish species of the Caspian basin, reduction of their stocks and catches. If in 1932-1936, yearly catches of commercial fishes (without sprats) of all fisheries (except for Iran) made 394 thousand tons, in 1951-1955, they decreased up to 283 thousand tons and in 1990-1995 – up to 81 thousand tons (Table 7).

Since 1950, in order to compensate unharvested valuable commercial fishes, sprat fishery in the Middle and Southern Caspian was intensified. In the 1960-1980s, yearly 300-400 thousand tons of sprats were landed. Catches of sprats by the Caspian littoral states (except for Iran) in 1997 constituted about 90 thousand tons.

Sturgeons are of the greatest consumer value (Fig. 14, 15). As a result, sturgeons became an attractive target for poachers. Main harvested species of sturgeons are the Russian and Persian sturgeon, Beluga and Stellate sturgeon. The ship sturgeon is rare. It’s fished only in Kazakhstan. The spawning grounds of the ship sturgeon in the Kura have lost its commercial importance. The sterlet is a freshwater species. It ranges only in the Volga.

Three sprat species inhabit the Caspian Sea: common, big-eyed and anchovy. Habitats of the two latter species are the Middle and Southern Caspian, the common sprat occurs all over the Caspian. The anchovy sprat is the main fishing target (85 % of the total catches). Sprats are mainly harvested on the shelf of the

Southern Caspian and in smaller volumes in the Middle Caspian.

Table 6. Dynamics of fish catches in the Caspian Sea (by Kosarev, Yablonskaya, 1994).

Fish	1932	1940	1950	1960	1970	1980	1987
Sturgeons	16.9	7.5	13.5	10.1	16.1	25.0	19.1
	100	44.4	79.9	59.8	95.3	147.9	113.0
Salmons	0.90	1.10	0.40	0.01	0.01	0.01	0.01
	100	122.2	44.4	1.1	1.1	1.1	1.1
Semi-anadromous	241.9	165.1	202.9	112.4	44.3	14.7	31.6
(vobla, bream, zander, carp)	100	68.2	83.9	46.5	18.3	6.1	13.1
Fluvial	62.2	25.8	34.0	32.1	42.8	37.6	28.3
(wels, pike, ruff, tench)	100	41.3	54.7	51.6	8.8	60.4	45.5
Shads	81.8	136.3	56.1	54.9	1.8	1.2	1.7
	100	166.9	68.6	67.1	2.2	1.5	2.1
Mullets	–	0.1	0.3	0.8	0.6	0.2	0.3
		100	300	800	600	200	300
TOTAL	403.7	336.1	307.2	210.3	105.6	78.7	81.0
	100	83.2	76.1	52.1	26.2	19.5	20.1
Kilkas	6.9	8.9	21.6	176.0	423.2	30.8	299.0
	100	129.0	13.0	2550.7	613.3	4417.4	4333.3
TOTAL	410.6	345.0	328.0	386.3	528.8	383.5	380.0
	100	84.0	79.9	94.1	128.8	93.4	92.5
% of all fishes except of kilkas	98.3	97.4	93.7	4.4	20.0	18.6	21.3

Note: numerator – thousand tons, denominator – % of catches compared to 1932.

Table 7. Dynamics of fish catches in the Caspian Sea (thousand tons)

Objects	Years							
	1930	1940	1950	1960	1970	1980	1985	1990
Sturgeons	16.9	7.48	13.48	10.14	16.08	25	21.08	13.5
Shads	81.82	136.5	56.08	54.88	1.85	1.17	3.49	2.14
Kilkas	6.94	8.94	21.64	175.96	423.2	304.7	269.7	233.8
Big ordinary fish	127.5	123.7	159.1	60.27	53.2	23	29.34	39.9
Vobla	130.8	51.44	59.62	64.06	12.45	5.8	8.6	20.8
Small ordinary fish	50.45	17.87	19.93	20.29	21.47	23.16	11.65	10.8
Mullets	-	0.07	0.3	0.76	0.64	0.17	0.24	0.16
Salmons	0.91	1.14	0.44	0.01	0.001	0.02	0.03	0.01
Lamprey	0.69	0.27	0.1	0.01	-	-	-	0.05
Other fish	0.39	2.01	0.88	0.16	0.05	0.001	-	-
Pondfish	-	-	-	-	1.98	4.09	7.45	9.2
Crayfish	-	-	-	0.1	0.07	0.1	0.01	0.006
Seal (thous. ind.)	74.6	109.6	28.71	22.38	69.2	17.32	20.93	22.62
TOTAL	416.5	349.5	331.6	386.64	530.9	387.2	353.7	330.3

The commercial stocks of herrings used to be considerable in the 1960s have sharply dropped in the second half of the 20th century. Only recently, they have become to restore. Now, black-backed shads, Dolginka shad, Caspian and big-eyed shads, and Southern Caspian herrings are commercial species of herrings. Herrings are harvested in the delta of the Volga (black-backed shad), at Azerbaijan, Turkmen and Iranian coasts. Mullets (golden and gray) were introduced into the Caspian Sea from the Black Sea. Due to introduction of these species, a large herd of valuable commercial fishes was established. Its main inhabitants include the Southern Caspian. The maximum catches of mullets in Turkmenistan waters were recorded in the middle of the 1950s (up to 550 tons).

Salmons are represented by two species: Caspian trout and Caspian inconnu. The feeding grounds of the salmon are located along western and southern shores of the Middle and Southern Caspian. The Caspian trout forms several shoals, which are linked to basins of several rivers feeding the Caspian: in the Southern Caspian it is the Kura, Lenkoranka and Astarinka. Prior to damming of the river Kura, it was the main Caspian trout fishery in the Caspian (0.5-3.5 thousand fishes). In order to compensate damage inflicted to salmon stocks by damming of the river Kura, two hatcheries were constructed in Azerbaijan. A trend of disappearance of this species, in view of uncontrollable poaching, is observed.

The population of the Caspian inconnu has reduced to a minimum. Now, it is fished only on the Volga. In the same time, a disastrous reduction of its population is observed. The total catch of 1998 constituted 10.2 tons. At present, the Caspian inconnu is fished only for monitoring and for reproduction purposes.

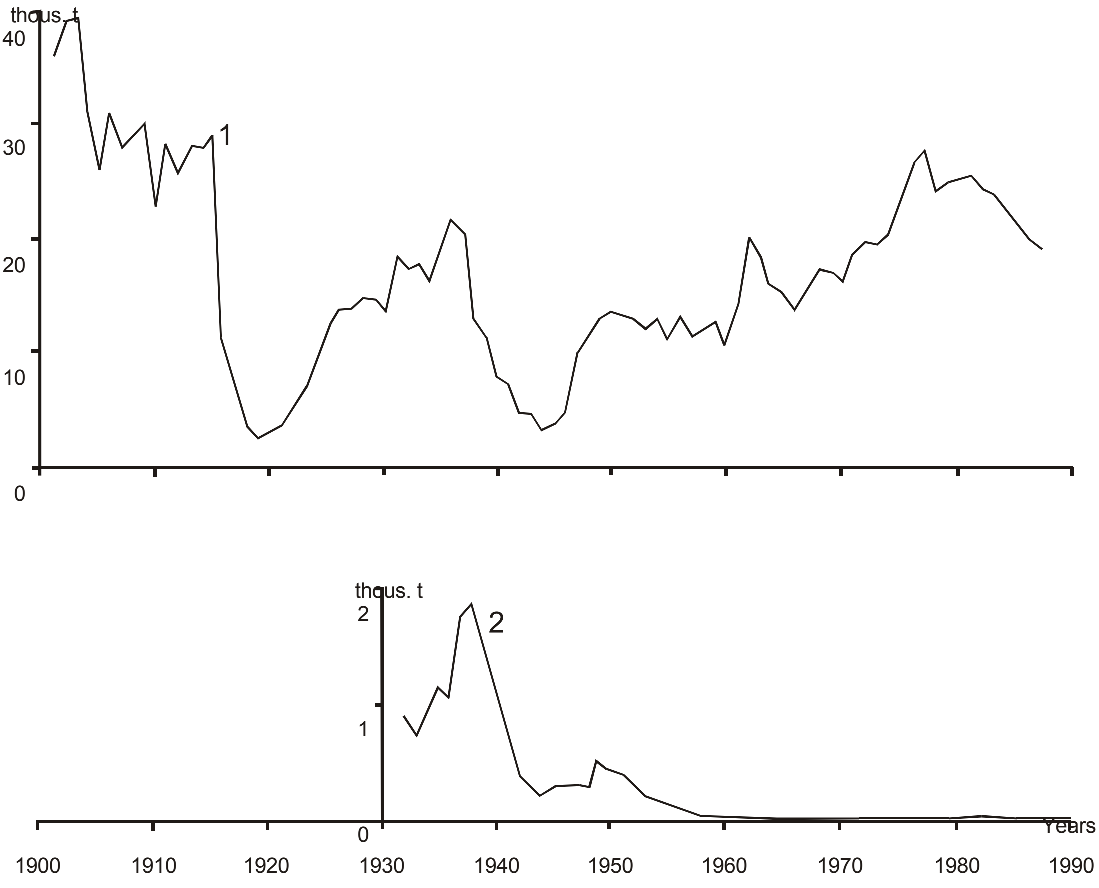

Figure 14. Dynamics of sturgeon catches (1) and salmons (2 in the Caspian Sea, thousands of tons.

(by Gurevitch, Lopatin, 1962; Catches of Fish …, 1985, 1986; Kaspiiskoye Morye. Ichthyofauna …, 1989).

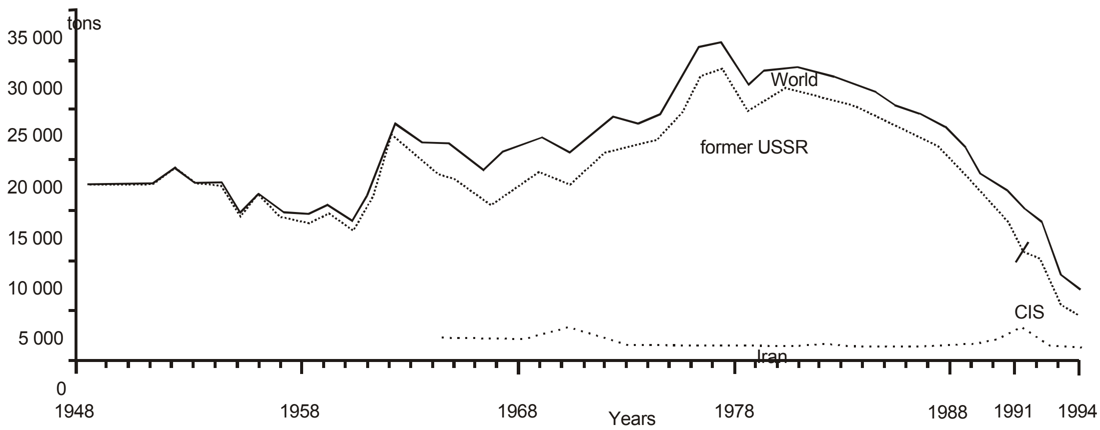

Figure 15. The world-wide catch of sturgeon fishes, 1948–1994. *(by Zonn, 1999)*

Kutum, barbel and zahrte are inhabitants of the Southern Caspian. In the Northern Caspian, the kutum almost does not occur.

The Asp common is a widespread predatory species harvested in all Caspian littoral states.

Semi-anadromous and freshwater fishes of the Caspian basin - Caspian roach, Caspian bream, zander, common carp, catfish, pike, crucian carp, rudd, tench, silver bream, and perch – are traditional and important fishing objects. The life cycle of typical semi-anadromous fishes (Caspian roach, Caspian bream and zander) is linked to lower stretches of the rivers where they reproduce, and estuarine areas of the sea – feeding grounds of young and adult fishes. The common carp and catfish should refer to semi-anadromous fishes, as they migrate and a part of their populations, apart from an avant-delta, fattens in the sea. Invaders such as the silver carp and the white grass carp are fished in southern regions of the sea.

Freshwater species are fished in river estuaries: a pike, rudd, tench, crucian, catfish, loach, perch etc.

In the 1990s, as a result of uncontrollable poaching and decrease of artificial reproduction, the population of all sturgeon species, Caspian trout, Caspian inconnu, khramulya, Danubian bleak, barbel and zahrte has decreased. These species, especially sturgeons and salmons, are threatened in connection with a considerable decrease of fries releases from hatcheries.

Two crawfish species are harvested in Turkmenistan – pachypods and palpods.

Under obvious reduction of fish catches in the Caspian Sea, they do not correspond with available stocks and are accounted for an economic recession in the fish industry. There are no real threats for majority of commercial species.

Nevertheless, fishing, along with other factors (damming of rivers, pollution), has led to disappearance of some fish species from catches. In the 1920-1940s, Caspian lamprey, Volga herring, Caspian trout, Caspian inconnu, which total catches in the Caspian basin amounted to 80 thousand tons, used to be usual commercial species. Now, these fishes are listed in the Red books of Caspian littoral states.

The seal is the only mammal inhabiting the Caspian Sea. It has a long commercial history characterized by yield fluctuations during 2-3 centuries. Only in the 20th century, the range of fluctuations of the level of seal harvests reached several hundreds thousands animals. Further intensification of production could have led the loss of the valuable commercial species. Only, strict control and change of the profile of the industry to fur production, conducted in the 1966-1970s, have allowed for stabilizing the magnitude of the population of the Caspian Seal at the level of 500-600 thousand animals with the brood stock in the amount of 90-100 thousand females.

Specially conducted researches showed that within the last decades, certain destabilizing processes have been observed in the population of the Caspian Seal (Ivanov, Sokolskiy, 2000). The mass examination of animals before a breeding season at autumnal rookeries in 1989-1990 has revealed that up to 73.4 % of females dropped out of reproduction for different reasons (pure barrenness, pathology etc. A similar situation repeated in five years. Naturally, such sharp changes of barrenness could help influencing on the magnitude of population, which since 1986 to 1995 reduced by approximately 20%. The crisis of reproduction of the population, in turn, is a corollary of unfavorable processes happening in the ecosystem of the Caspian Seas. This resulted in mass deaths of seals in 2000, which begun in the northeast of the Caspian and spread to all over the sea. A prospective reason of the deaths is distemper on the background of cumulative polytoxicosis and salmonellosis.

The seals are bagged on ice in wintertime in correspondence with allocated quotas. Largely, newborn pups (white-coat seals) with fluffy white fur are hunted. In connection with economic difficulties, seal hunting has been stopped by all countries since 1997, except for Russia. Russia has stopped hunting since 1998.

Fishery

There is opinion (Ivanov 2000) that in the time of Golden Horde the main food fishes in this region were sturgeons and Caspian inconnu. Just only in the middle of the 19th century when stocks of these species began to be exhausted, here one have started to fish large ordinary fishes – carp, bream, wels, pike-perch, etc.

The main cause of this was exhaustion of sturgeon fish stocks due to overfishing. In order to clear up the causes of decreasing profitableness of fisheries the government sent expedition headed by academician K. Baer. He had seen that fishery was directed to momentary profit. Fishing was in the season when fishes are migrating to Volga for spawning. Amount of caught fishes was so large that only the most valuable small part was taken whereas the rest was thrown out as useless. In order to protect and restore fish stocks K. Baer recommended prohibiting the most injurious methods of fishing and fishing on the wintering places, to establish an institution supervising fishery and to work out a project of new rules of fishery.

In spite of poor state of fish stocks fishery was the main branch of regional economics. Since the end of XIX century as fishery in Volga was decreasing fishery in the Caspian Sea began developing. In 1913 fish catches in the sea have reached 590 thousand tons, from those there were 590 thousand tons of shad and 136 thousand tons of vobla (Ivanov and Mazhnik 1997).

By 1930-1940s fishing with sweep-net has started and became the main in region. The same time fishing of kilkas has started. After the Second World War new technique of kilka catching by light with special pumps allowed to increase its catches in 1970 up to 423 thousand tons or 80% of total fish catches on the Caspian Sea

In 1960s it became clear that fishing with nets in the Caspian Sea is hardly damaging to fish stocks, especially sturgeon stocks, because together with other species the huge amount of immature sturgeons are caught. After strong struggle of science with fishing industry in the mid 1960s fishing in the sea was prohibited and as a result catches of sturgeons increased and reached 20-27 thousand tons in 1975-1986 (Ivanov and Mazhnik 1997).

Till the mid XX century state of commercial fish stocks first of all depended on the intensity of fishery and mistake in its organization. But then impact of another anthropogenic factor – regulation of Volga – began to affect.

In the 1930s USSR authorities began reconstruction of Volga basin. It was supposed that reservoirs will allow to solve old problem of shipping owing to keeping higher water level where shipping has difficulties in low-water season and provide national economy with cheap electric power.

As a result of this reconstruction areas of sturgeons spawning have decreased by 7-10 times and now they are about 400 ha in the tail water of Volgograd power dam.

At that low of integral resource has began its realization. Some branches of nature management began consume water resources of the same ecosystem more intensively. But these resources supported reproduction of fish stocks. Spawning areas of Caspian inconnu and sturgeons being the base of fishery still some centuries ago were just where were being built dams and created reservoirs. As a result towards 1980 catches of valuable commercial fishes has decreased to 78 thousand tons.

In the 1960-1980s total annual average damages from man-caused to fish industry of Volga-Caspian were 279.1 thousand tons (including 41.6 thousand tons of sturgeons). The highest damage was from construction of dams and regulation of flow – 241.0 thousand tons (Table 8) (Mazhnik 2002).

It has become apparent the rule of ecosystem seral rejuvenation. Initially there were fished sturgeons being on higher level of food chain. Then as resource was being exhausted and the food chain shortened ordinary fishes were fished. And finally it was fished kilka being closer by the beginning of food chain. Though rejuvenation of ecosystem has allowed increasing in the volume of catches but there quality was lost. High quality products from sturgeons were replaced by products from kilka.

In the first decade of the XX century is a steady decline in the indices of production in fisheries and aquaculture.

Fixed assets of large and medium-sized commercial organizations in the field of fisheries and fish farming is characterized by considerable degree of deterioration and very low rates of renewal and liquidity. Many of these organizations are unprofitable. Large and medium enterprises in the fishing and fish farming are unprofitable as a whole. Small businesses have some profit.

Table 8. Annual average loss on fisheries caused by anthropogenic factors (by: Mazhnik, 2002).

Factors	In the 1960-1980s			In the 1990s			
	Natural loss, thousand tons	Sturgeons, thousand tons	Cost of loss, million Rubles (prices of 1982)	Natural loss, thousand tons	Sturgeons, thousand tons	Cost of loss, million Rubles (prices of 2000)	Sturgeons, million Rubles (prices of 2000)
Hydro-power engineering	241.0	40.4	568.0	37.0	7.0	2802.8	2450.0
Irretrievable water consumption	25.3	4.2	50.9	–	–	–	–
Diversion facilities	12.8	no data	18.2	5.5	no data	64.8	–
Gaseous condensate complex	–	–	–	5.0	no data	58.8	–
TOTAL	279.1	41.6	637.1	47.5	7.0	2926.4	2450.0

Disadvantaged are also many enterprises for processing and canning of fish production in the Astrakhan region. These companies are potential bankruptcy and some of them are unprofitable.

The base of exports are frozen fish fillet and frozen fish. With the end of the official fishing of sturgeons exports of sturgeon caviar, which at the beginning of the XX century gave about half of export earnings, has ceased.

In the structure of gross regional income the portion of enterprises of fisheries and aquaculture in 2004-2006 year were less than 0.7%.

The number of vessels in service is much less than reported. There was deterioration in the quality of the fleet, especially fishing one. The technical state of many ships does not satisfy regulatory requirements and the current level of technology.

Undermining the resource base and trying to squeeze everything possible out of existing capital assets, paying no attention to their renewal have led to social problems - reducing the number of jobs in this field.

In addition, the course on the economic impact of fisheries and the so-called unreported catches – catches by poachers and hidden part of fishermen's official catches. Unaccounted catches for most ordinary fish reaches 200-300% of the official catch, higher rates are for vobla and sturgeon (Table 9). As a result, fish populations are currently under extreme anthropogenic pressure. Because of poaching of sturgeon on migration routes in the Northern Caspian intensity of their entry into the Volga is weakened. According to official sources, confiscated sturgeons in 2004 reached 200 tons, while experts estimate the true unaccounted catches as 2000 tons (Karpyuk et al. 2005).

Table 9. Unaccounted catches in 2004 (by: Karpyuk et al. 2005).

Fish species	Catches, thousand tons	Unaccounted catches, %	Unaccounted catches, thousand tons	Cost, million Rubles (in prices of 2004)
Sturgeons	0.2	1000	2.0	1346.8
Vobla	1.3	550	7.15	269.5
Bream	10.0	134	13.4	427.5
Pike perch	0.315	694	2.185	165.2
Wels	4.039	143	5.761	234.3
Carp	0.6	733	4.4	180.4
Pike	3.06	103	3.14	191.0
Crucian carp	2.366	62	1.234	31.9
Rudd	2.918	23	0.682	13.4
Tench	1.083	20	0.217	4.9
Crawfishes	0.007	286	0.02	1.6
TOTAL	25.888	–	39.039	2867.3

Exotic species

One of the most ancient groups of invaders into the Caspian is Arctic invaders. Most probably, they have penetrated here during the glaciation period. The following organisms can serve as an example of arctic invaders.

One species of Polychaeta from the family Sabellidae - *Manayunkia caspia* probably penetrated into the Caspian from the Arctic region. There are many other arctic invaders in the Caspian Sea: *Limnocalanus* *grimaldi*, *Mesidothea entomon glacialis*, *Pseudalibrotus caspius*, *P. platyceras*, *Pontoporeia affinis microphthalma*, *Gammaracanthus loricatus caspius*, *Mysis caspia*, *M. microphthalma*, *M. macrolepis*, *M. amblyops*, *Stenodus leucichthys*, *Salmo trutta*, and *Phoca caspia*. How and when all these organisms invaded the Caspian Sea is not known.

Plankton crustaceans from the family Cercopagidae should, probably, refer to northern invaders. According to data osmoregularoty and molecular-biological researches of representatives of the genus *Cercopagis* can not be consider as typical Caspian endemics. These crustaceans refer rather to the group arctic or freshwater invaders of the Caspian, than to true autochthonous fauna of the Caspian. In our opinion, ancestors of the modern Cercopagis could penetrate into residual reservoirs of Paratethys in time of the Akchagyl or Apsheron transgressions (2.5-1.1 million years ago). Thus, the modern *Cercopagis* and *Bythotrephes*, obviously, had a common ancestor, which lived on the margins of the Baltic glaciation shield. A part of ancestors, apparently, remained in Palearctic region and gave origin to *B. longimanus*, and another part penetrated into the ancient Caspian, when its waters overflowed far in the north in the vicinity of the mouth of the modern Kama. Here, in the Akchagyl or Apsheron sea, a fast evolution of the ancestors of the forms *Cercopagis* (accelerated phenomena of cyclomorphosis, parthenogenetic and hamogenetic cloning, hybridization, etc.) begun here. These specific evolutional processes, obviously, ensured unusually fast (a bit more than 1 million years) and extensive adaptive radiation of *Cercopagis*.

The introduction of freshwater organisms into the Caspian Sea happened several times during its greatest desalinization. The gastropod mollusks are considered the most ancient freshwater elements. To certain degree this was facilitated by the nature of the salinity of the Caspian, essentially differing from oceanic water by its composition. The number of freshwater invaders in the Caspian is so high, and their presence is irregular (Chuykov, 1994).

According to data of Zenkevich (1963) the fauna of Atlantic-Mediterranean origins is represented by: 1 species of Turbellaria, 1 species of Coelenterata, 2 species of Polychaeta, 1 species of Copepoda, 2 species of Cirripedia, 3 species of Decapoda, 3 species of Mollusca, 2 Bryozoa and 2 (6) species of fishes.

Atlantic and Mediterranean invaders penetrated into the Caspian Sea 3 times:

1. The very first invaders penetrated during the Khvalyn period, some 50 thousands of years ago. They came by a natural way through the Kuma–Manych strait between the Black and the Caspian seas. They included 7 species: *Zostera nana, Cardium edule, Fabricia sabella, Atherina mochon pontica, Syngnathus nigrolineatus, Pomatoschistus caucasicus, Bowerbankia imbricata*.

2. This group of invaders appeared in the beginning of the 20th century or a little bit later. Some of invasions were natural, and some were artificial. 4 species penetrated by a natural way, without human participation and only accidentally (probably with water in small wooden vessels): *Rhizosolenia calcar-avis, Mytilaster lineatus, Leander squilla, L adspersus.* Diatom *R. calcar-avis* appeared in the Caspian Sea in 1930, and by 1936 made 2/3 of the total biomass of phytoplankton. 5 species of fishes and invertebrates were intentionally introduced by man: *Mugil auratus, M. saliens, Pleuronectes flesus luscus, Nereis diversicolor, Abra ovata*. *Mytilaster lineatus* during further distribution seized habitats of similar endemics and partially superseded them. For example *Dreissena polymorha andrusovi* and *Dreissena elata*, which prior to the invasion of *Mytilaster* were widespread species in the Middle and the Southern Caspian. As to polychete *Hediste diversicolor* and bivalve *Abra ovata*, these species became a supplement to the local fauna; they did not compete with native species, but coexist with them.

3. Invaders of the middle of the 20th century were last ones. All of them penetrated into the Caspian Sea through the Volga–Don Canal opened in 1954. It was a rather natural (probably with ballast waters of large ships or as fouling) invasion, than deliberate. In the end of the 1950s, 7 species pene-

> trated: *Balanus impovisus, B. eburneus, Membranipora crustulenta, Ceramium diaphanum, C. tenuissimum, Ectocarpus confervoides, Polysiphonia variegata*. More than 9 species of algae and 9 species invertebrates have penetrated into the Caspian a bit later. Algae: *Acrochaeta parasitica, Ectochaeta leptochaeta, Enteromorpha tubulosa, E. salina, Ectocarpus confervoides* v. *fluviatilis, Entonema oligosporum, Acrochaetium deviesii, Ceramium diaphanum, Polysiphonia variegata*. Coelenterates: *Moerisia maeotica, Bougainvillia megas, Blackfordia virginica*. Bellflowers *Barentia benedeni*, polychete *Mercierella enigmatica*, crustaceans *Balanus impovisus, Balanus eburneus, Rhithropanopeus harrisii*, pearlweed *Conopeum seurati* (Karpevich, 1975). Soon after an introduction *Ceramium diaphanum* become a dominating species in the Northern Caspian. Then another 2 species penetrated into the Caspian from northeastern coast of Northern America through the Sea of Azov and the Volga–Don Canal: jellyfish *Blackfordia virginica* and crab *Rhithropanopeus harrisii*.

After this, some more species penetrated into the Caspian Sea through the Volga-Don Canal. For example, 6 species of marine algae were found by Zevina. 2 species of marine Cladocera: *Pleopis polyphemoides* and *Penilia avirostris* were registered by F. Mordukhay-Boltovskiy and N. Aladin.

A delibarate introduction of commercial and fodder aquatic organisms exerted essential influence on the biodiversity of the Caspian. So, according to data of A. Karpevich (1975), in the period with 1930 on 1970, at least fish 9 species of were introduced into the Caspian: Glos's flounder *Pleuronectes flesus luscus*, topknot *Rhombus maeoticus*, mullets *Mugil auratus* and *M. Saliens*, white grass carp *Ctenopharingodon idella*, white silver carp *Hypophthalmichtys molitrix*, motley silver carp *Aristichthys nobilis*, chum *Oncorhyncus keta*, hampback *Oncorhyncus gorbuscha*. Of other introduced fishes – salmon *Salmo gairdneri*, striped perch *Morone saxatilis*, *Mugil so-iuy* – results are not known yet. Of invertebrates, organisms brought from the Azov-Black Sea basins were successfully introduced polychaete worm *Hediste diversicolor*, bivalves *Abra ovata* and shrimp *Palaemon elegans*.

It is possible that some more atlantic-Mediterranean species are currently invading the Caspian Sea, and will be registered by scientists in the nearest future (Dumont, 1995). The comb-jelly *Mnemiopsis leidyi* has invaded the Caspian recently (Ivanov et al., 2000). This species of comb-jellies has negatively influenced industrial fisheries in the Black sea and first of all on catches of plankton-eating fishes (Comb-jelly …, 2000).

Recently, another two species of the Black Sea origins have penetrated into epilimnion of the Caspian Sea. These species are plankton species of Copepoda: *Calanipeda aquaedulcis* and *Acartia clausi*. Invaders from the Atlantic and Mediterranean will continue appearing in the Caspian unless in next years or, probably, decade a new balance between native species and invaders is established. It is very difficult to say when such a balance is in place, because now the Caspian environment is unstable because of climate changes, anthropogenic pollution and some other important aspects of environmental impacts. Usually changes in abiotic and biotic components of ecosystems of the Caspian Sea support invaders.

Threats to the biodiversity of the Caspian

Environmental problems of the Caspian Sea are multiple and various in their origin. On one hand, they are caused by the commercial use of the sea; on the other hand, human activity impacts coastal areas, including input from rivers in the Caspian. As the Caspian is an inland water body, anthropogenic impacts on catchment area accumulate here. Anthropogenic impact on the Caspian ecosystem occurs concurrently with various natural endogenous and exogenous processes. It is primarily sea level changes, periodical seismic activity, surges and retreats, mud volcanoes and neo-tectonics. Special features of the Caspian include constant alterations of its area, volume, configuration of the coastline and water column structure. Anthropogenic activity, as well as a natural impact, can have a chronic (long term) or acute (short term) effect.

Regulation of rivers that flow into the Caspian is one of the most significant anthropogenic impacts on the biodiversity of the water body. In the 20th century, in the early 1930's, many reservoirs were built on the Caspian

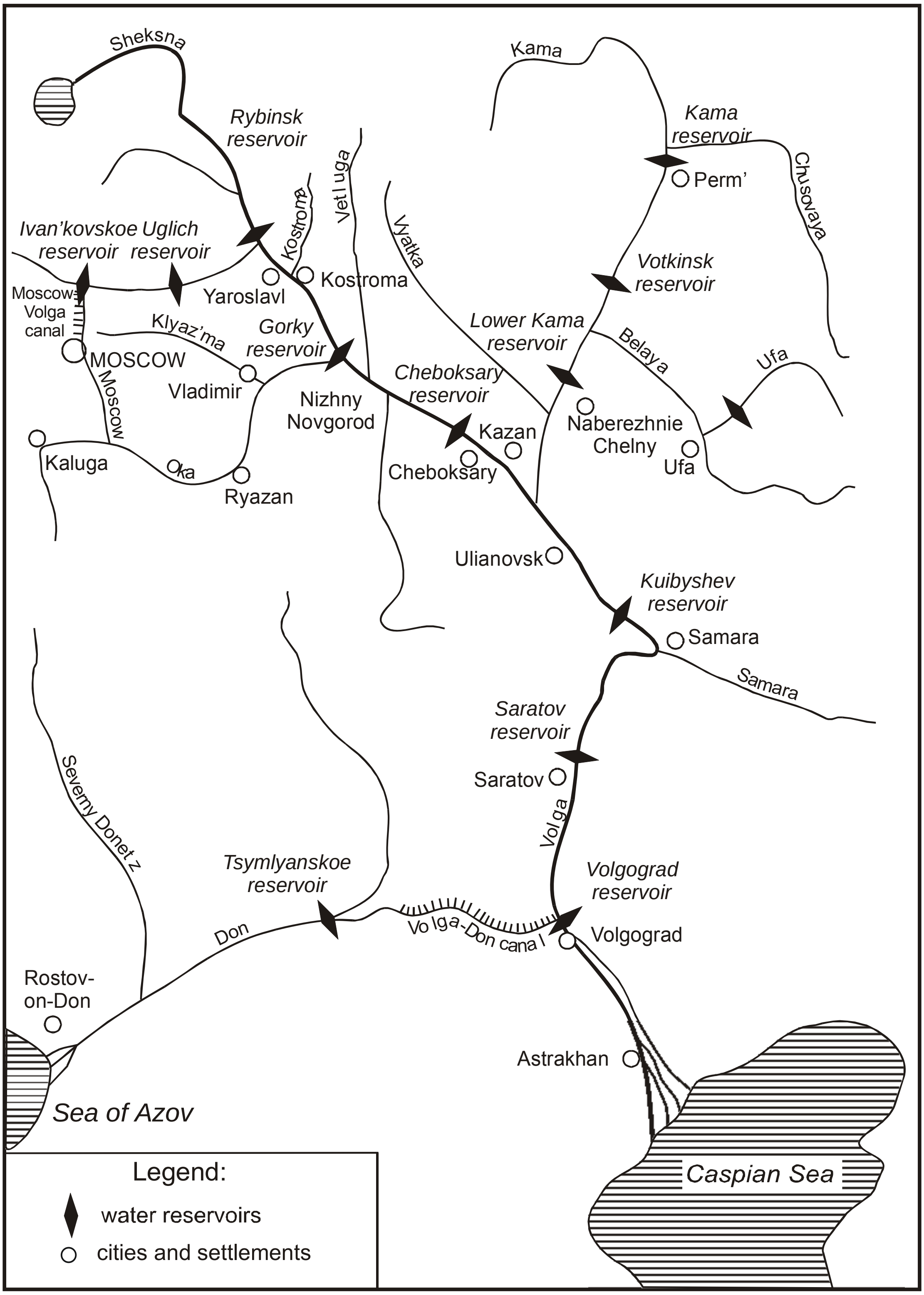

Figure 16. Scheme of Volga-Kama hydroelectric power stations cascade. *(by "Vozrozhdenie Volgi …", 1996)*

rivers for the purposes of hydroelectric power industry. At present the Volga is surrounded by a chain of huge man made lakes or reservoirs (Fig. 16). The capacity of the water bodies is over 180 km^3. Every year 8-10 km^3 of water are lost from evaporation which is approximately 3% of the annual flow of the Volga (Zonn, 2000). Water from the Caspian rivers is used for irrigation which also reduces the annual flow. Water used for irrigation of fields is a loss to the Caspian.

At present the Caspian lacks about 12% of river input. During the period of water reservoir infill water loss was even higher. It can be concluded that, if not for the river regulation (water intake), the level of the Caspian would have been at least 1-1.5 m above the present level (Georgievsky and Shikhlomanov, 1994). Regulation of river flow has both chronic and acute impact. Chronic impact can be described as a shoaling of river deltas. For instance, lack of river input reduced the area of delta vegetation, caused loss of reeds, cat's tail, bushes. Loss of vegetation resulted in loss of aquatic and coastal fauna. Not only deltas suffered the consequences of river regulation. Many anadromous and semi-migratory species were deprived of their natural spawning grounds. As river deltas became shallower, fish could not migrate to rivers for spawning. Those individuals that managed to get to the rivers, encountered the problem of hydropower plants. The impact of dam construction on sturgeon and salmon was the most severe. The species cannot overcome obstacles such as dams even with fish ways and fish lifts. The loss of natural spawning grounds resulted in almost complete loss of the Caspian salmon population; as for the sturgeon, it is bred in fish hatcheries. The annual loss of sturgeon due to hydropower plant activity is over 10,000 tons per year (Vozrozhdenie Volgi …, 1996). State report "Status of environment of the Russian Federation in 1994-95" contains data about the construction of dams at the Volga that resulted in the reduction of spawning grounds from 3-4 thousand hectares to 0.4 thousand hectares which is 12% of the previous grounds in the delta and food plain of the Volga and the Akhtuba. The only available natural spawning grounds are located on the Ural and the Iranian rivers where no dams were built.

Accidental discharges of hydropower plants have an acute (short term) impact on the Caspian. The discharges occur in spring when reservoirs are flooded with snow water and accumulation of high amount of water is a threat to dams. To prevent this, engineers discharge a high amount of water in a jet stream. The man made floods damage bottom and coastal ecosystems and make difficult it for spring spawning migrations. On the other hand, engineers can minimize river input downstream from the dam during low-flow periods. They keep the level high in the reservoirs to provide continuous work for water turbines, so the riverbed downstream from the dam almost dries up. This is particularly dangerous for shallow river arms and flood plains. A chain of dry flood plains can be seen along the Caspian rivers during dry years. Fortunately, dry years are not typical for the Caspian, and such tragedies are uncommon. However, just one dry water system is enough to make unrecoverable damage to the biodiversity of the environment.

The impact of water turbines on aquatic life deserves a special mention. Entrained fish and invertebrates die or become badly damaged. Thus, every hydropower plant makes significant damage to the biological diversity of the aquatic community.

Caspian rivers carry a high amount of pollutants from catchment areas produced by both industrial and agricultural anthropogenic impact. This can result in the Caspian becoming severely polluted. Fortunately, only a small proportion of diluted and suspended pollutants reach the sea, as water reservoirs serve as man made sumps or purifiers. Pollutants accumulate in bottom sediments of these huge man made lakes. If it were not for the reservoirs on the rivers, we would not be able to maintain the present the biodiversity of Caspian deltas and adjacent areas. This proves that the interface between the negative and positive anthropogenic impact is delicately balanced.

Water reservoirs on the Caspian rivers hold not only pollutants but also nutrients. The retention of chemicals that are vitally important for plant life cannot be considered as positive. Disruption of nutrient input into the

Caspian significantly reduces the trophic potential of deltas and adjacent areas of the Caspian Sea and has a negative impact on its productivity and biodiversity.

The biodiversity is of a high commercial significance. Biological resources of the Caspian (mainly fish resources) are estimated as 5-6 billion USD per year (Glukhovtsev, 1997). High cost of fish resources threatens the biodiversity of the most important commercial species.

The annual catch in the Caspian (without sprat) reduced from 283 thousand tons in 1951-55 to 81 thousand tons in 1990-95. However, reduced catches of the majority of species in the Caspian cannot be related to the reduction of resources and can be a result of an economic recession in the fishing industry. There is no real threat to the majority of commercial species.

However, fishing along with other factors (rivers regulation, pollution) resulted in the complete loss of some species of fish and Cyclostomata. In the 1920-40's typical commercial species were Caspian lamprey, Volga shad, Caspian trout, Caspian inconnu. The total catch of these species was about 80 thousand tons. At present the species are included in the Red Books.

About 90% of world sturgeon reserves are concentrated in the Caspian, so the Sea can be considered a global genetic fund for the species. At present there is a real threat to the survival of the species. Nowadays the catch of sturgeon in the Caspian has reduced from 25,000 tons per year to 1,000 tons. Before 1962 when fishing of sturgeon was legal, commercial fishing made a significant damage to the population, as many juvenile fish were caught. In late 1970's over-fishing reached 30%.

At present fishing and poaching is the main threat to the biodiversity of sturgeon. After the Soviet Union collapsed, Fishing Regulations were not observed, fish control authorities disintegrated, marine fishing of sturgeon resumed. Russian specialists believe that illegal fishing increases official catch by a factor of 11, i.e. by a factor of 8 offshore and three times in rivers.

The problem of over-fishing affects other species. Thus, in Iran over-fishing of Caspian trout, bream, zander, along with the damage of their habitats and spawning grounds, resulted in complete loss of these species. Zander disappeared due to massive catches in Azerbaijan and Turkmenistan.

Catches of other species is far from scientific methods and regulations, so it is not a threat and will not be a threat in the near future. Over-fishing is less dangerous for species with a short life cycle. Even if the abundance of the species reduces, it recovers within a few years under the right conditions. To recover the reserves of sturgeon with its long life cycle will take at least 30-50 years.

Caspian Sea level change (Fig. 17) is one of the most important natural impacts on the biodiversity of this huge water body (Dumont, 1995). The impact can be both chronic (long-term) and acute (short-term). A long-term impact is historical natural sea level fluctuations, which can be attributed to changes of climate and river discharge into the Caspian. Acute (short-term impact) is seasonal or wind-induced changes of level. It is known that the seasonal changes of level of the North Caspian can reach almost 0.5 m, while under the influence of surges it can rise for 1.5-2 m. At the west of the North Caspian surges cause inundation of the coastline up to 30 km onshore, while retreats cause exposure of 10 km of the seabed.

Chronic (long-term) of sea level changes impacts on the biodiversity of the Caspian. In the 20th century the sea level has been decreasing from the late 1920's – early 1930's till 1970's by almost 3 m. Such a significant change had a negative impact on its flora and fauna. Shallow waters of the North Caspian and deltas of Caspian rivers suffered the most. Shallow bays such as Kaidak and Mertviy Kultuk dried, the populations of the bays died. Deltaic areas reduced significantly.

Lowering of the Caspian Sea level created problems for navigation. Almost all the deltas of the Caspian rivers became so shallow that dredging had to be undertaken. Grabs, suction dredges and hydraulic jets contributed to damaging the delta's ecosystems. This activity cannot be considered a short-term impact as the equipment is used throughout the year, except for the winter period when there is no navigation. Changes in the level of the Caspian Sea can have a non-direct impact on biodiversity, via human activity. Sea level changes affect human interests, and response actions can make more damage to the environment than the change itself.

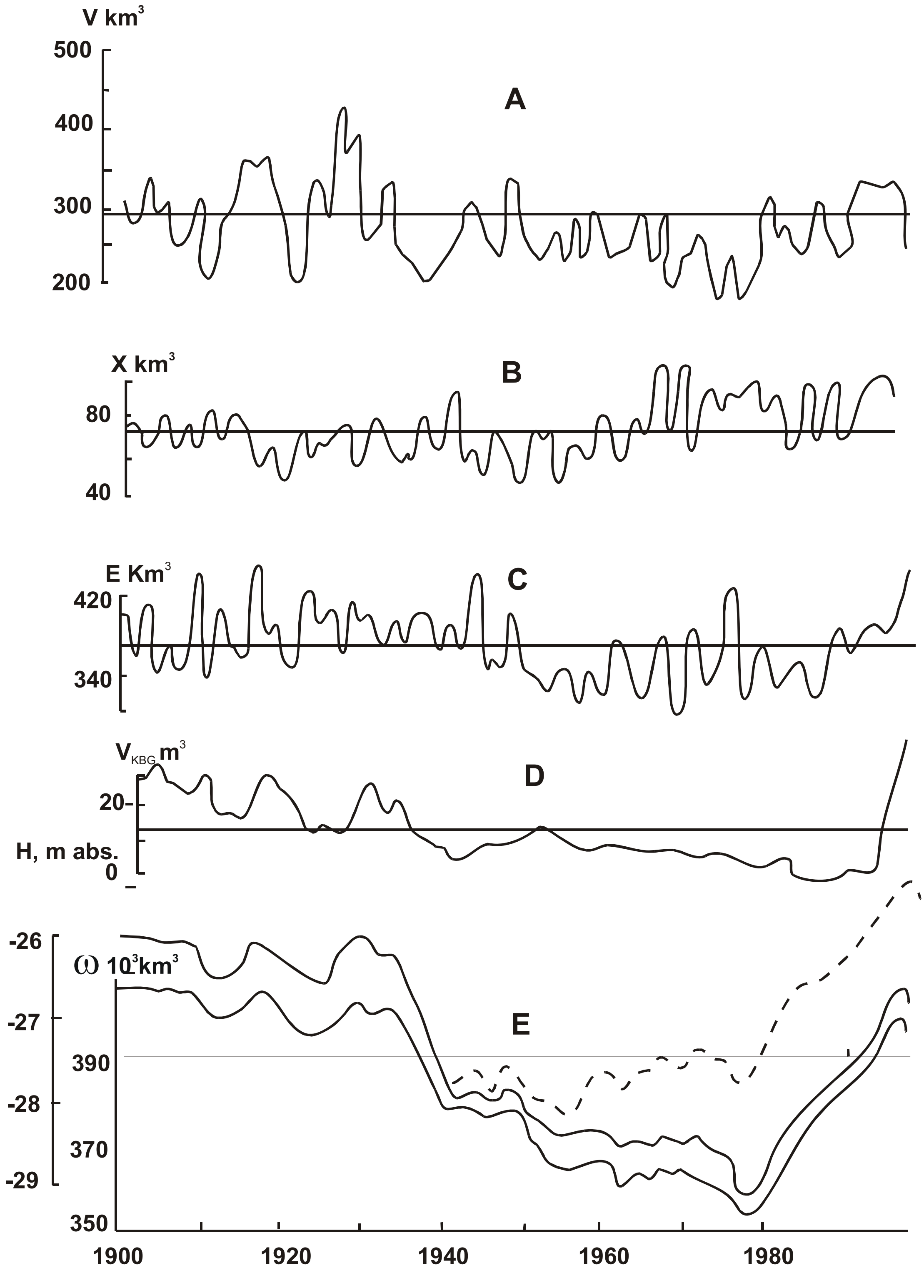

Figure 17. Changes of the Caspian Sea water balance, level and area from 1900 till 1996.
Dotted line – reconstructed level (without taking water).

Chronic (long-term) of the sea level rise impacts on the biodiversity of the Caspian. In the 20th century, the sea level has been rising from 1978 until approximately 1996. The total rise was about 2.5 m. This had a negative impact both on the biodiversity and economical activity. Sudden level rise damaged industrial, agricultural facilities and inhabited buildings located at the coast. A lot of pollutants were discharged into the sea which reduced populations and even resulted in localized death of animal and plant communities. First of all, flooding of oil production and transportation facilities had a damaging effect on the biodiversity.

A continuous sea level rise made significant damage to plant life in deltas of Caspian rivers.

The positive impacts of long-term sea level rise are the improvement of spawning ground conditions, increased spawning ground areas and reinforced water exchange between different sections of the sea, extension fresh water of buffer zone and increase of potential productivity in the North Caspian.

As a rule, short-term sea level changes do not have any significant impact on biodiversity of the Caspian.

Sea level rise does not allow endemic Caspian aquatic life to spread to the north due to desalination of the Caspian. When sea level reduces, its salinity increases and the abundance of true Caspian endemics increases.

Pollution is a significant threat to the biodiversity of the Caspian. The sources of pollution are industrial, agricultural and accidental discharges and sewage. The main flow of pollution comes from Volga.

The highest level of pollution was observed in late 1980s. Later input of pollutants into the sea reduced due to economic crisis, reduction of industrial capacity and abandonment of plants.

The most typical toxicants in the Caspian are petroleum hydrocarbons, heavy metals, phenol, surfactants and chloral-organic pesticides. Oil pollution is the most dangerous one. Interaction of aquatic life with petroleum hydrocarbons causes various physiological, biochemical and morphological changes in organisms. In some cases the changes can be reversible; otherwise they cause chronic pathological effects that result in death of fish.

The sources of oil pollution of the Caspian are primarily offshore wells during the drilling and production phases.

The following events can also result in oil pollution of the sea: underground and underwater maintenance of operating wells, accidental pipeline breaking, cleaning of effluent of oil refineries.

Excavation of hydrocarbon material is a special threat to the Caspian Sea bio-ecosystem. Exploration and production of hydrocarbons is the main source of negative environmental effects (Aladin and Plotnikov, 2000). An impact on biological resources begins at the time of the seismic oil and gas exploration.

Especially pernicious are blasting operations, which have led to mass mortality of sturgeon in the Caspian Sea. During drilling operations on the sea particularly especially alarming are discharges of liquid and solid wastes which accompany this process. The most severe environmental impacts occur from accidents on offshore platforms, which are inevitable in the exploitation of fields, and the Caspian Sea is characterized by severe storms and severe ice conditions in the northern part. As a result, if there is a large-scale drilling, water and sediment pollution with oil occurs. Incommensurably increases the risk of accidents with potential catastrophic loss of life on vast sea areas.

At the same time nobody intends to refuse extraction of Caspian oil. Moreover, Kazakhstan, Azerbaijan, Turkmenistan plans to increase hydrocarbon production in the area. Kazakhstan has covenanted to carry out exploratory drilling with a number of Western oil companies. In September 1994 Azerbaijan signed a contract with nine largest oil companies from America and Europe to develop new oil fields on the Caspian shelf for 30 years. Russia, after others Caspian littoral states began exploration, and (in 2010) extraction of hydrocarbons in the North Caspian Sea.

When several states connect their economic development with oil and gas in the Caspian Sea and adjoining areas, only efforts at international level may within the existing international rules to protect the fragile ecological environment of this region.

When it has become clear that as a result of the political position taken by the leadership of the Russian Federation activation of exploration activity in the North Caspian Sea is inevitable, the leadership of the Astrakhan region and the area occupied State Ecological Committee agreed position avoid negative environmental impacts of such activities. It was decided to prevent any discharge into the sea as drilling waste and household waste generated on offshore platforms.

It was developed the concept of "zero discharge", i. e. the minimum possible impact on the environment, later implemented in full by the company "LUKoil" in the Caspian Sea. In particular, this minimum during the exploratory drilling includes the emissions from power plants, water intake and discharge into the sea water used for cooling them, and discharge of cuttings near the well during drilling of the upper layer of bottom sediments. In this case there are minor damage of the upper layer of ground by supports of drilling rigs and anchors of ships destined for the rescue and transportation of waste on the coast. The principle of "zero discharge" shall remain in effect also during the development and exploitation of oil fields. However, the number of point sources of environmental impact is increasing, and in the aggregate it becomes more prolonged in time.

Nowadays economy of the Russian regions, as well as economy of other countries, is based on the Caspian mining and processing of hydrocarbons. In addition, shipbuilding and repair, which serve primarily the same industry, plays important role.

Exploitation of offshore hydrocarbon deposits can lead to the final degradation of the Caspian region ecosystems and, in turn, to negative socio-economic impacts on fisheries of Astrakhan region and Russia as a whole. Besides this the lack of coordination between the Caspian states on the exploitation of natural resources, finally, lead to unpredictable consequences for the ecosystem of the Caspian Sea, as indivisible natural complex.

Though oil toxicity (Nelson-Smith, 1977) is considered less dangerous for aquatic life than the toxicity of heavy metals, pesticides and some other organic pollutants, its impact on marine life must not be underestimated. Recent data confirm that even low oil concentrations have a toxic effect. This impact causes not the death of fish but deterioration of their physiological condition, feeding, reproduction and other life processes. Higher oil concentrations have a significant impact on fish. This and higher concentrations of crude oil and its derivatives reduce growth and development rate, fertility, reproduction capacity (Abbasov et al., 1991; Kasymov et a.l, 1992). Fertility of females of every next generation decreases a few times.

The second common toxicants are heavy metals. The most dangerous for biocenosis elements are lead, cadmium, zinc, and copper. Trace metals that accumulate in liver and gonads induce changes of the organs, and depress immune functions of organism. The highest concentrations of trace metals are typical for predators: catfish, zander.

Anthropogenic pollution of The Volga delta makes regular damage to commercial resources of the Volga and the Caspian. 13.7-89.3% of Caspian roach, bream, carp, silver bream, blue bream, perch and zander in delta of the Volga had symptoms of toxic poisoning prior to spawning.

Water of the Middle and South Caspian is described as medium-polluted or polluted. As a result, the biodiversity of benthic fauna reduced by a factor of 3 to 10.

Increase of anthropogenic stress in the ecosystem of the Caspian (pollution with pesticides, oil products, heavy metals) had primarily impacted sturgeon. It caused a disease of sturgeon not recorded previously which is gepatoxic hypoxia, the symptom of which is exfoliation of muscle tissue.

Chloral-organic pesticides that were widely used in agriculture, health protection and other activity in 1960-80, had a major impact on pathology of fish. During this period the most massive affection of sturgeon occurred (The Caspian Sea, 1996; Belyaeva et al, 1998).

Study of physiological and biological condition of sturgeon in 1990's revealed some decrease of pathologies compared to the level of 1960-70's. However, there was no return to relatively normal conditions. The toxicosis has become chronic with periods of improvement and acute condition.

Pollution is not a leading factor in formation of main biological productivity of the Caspian. At the same time, this factor is determining for localized areas where pollution is continuous.

Development of processes of eutrophication and pollution in fresh and saline waters causes reduction of fish reproduction. As estimated by specialists, the catch of semi-migratory fish in Volga-Caspian region (Caspian roach, bream and zander) would reduce for 60% due to three factors: regulation of rivers discharge, pollution and eutrophication of waters.

With excessive use of pesticides is connected problem of fish diseases (Aladin & Plotnikov 2000). In the end of XX century it was appeared earlier unknown disease of fishes, especially sturgeons. This disease or myopathy was produced by chronic toxicosis. So it was effect of excessive pollution of Volga River and Caspian Sea waters with high-toxic substances. They were without any control used pesticides getting to water bodies from fields and not-appointed depots, salts of heavy metals getting with untreated sewage from industrial plants on shores of Volga and Caspian and oil products. This disease resulted in dissection musculature, resorption of hard-roe, abnormal development of gametes and gonads. As a result recessive mutations were being accumulated, abnormal fish juveniles appeared and reproduction of fishes was depressed. All this was observed not only in long-living sturgeons but also in kilka having short life cycle.

The impact of introduced species on the biological diversity of the Caspian Sea falls into two groups: chronic (long term) or acute (short term) impact. Acute impact is identified during first years after the introduction of the new species into the Caspian. Its positive or negative impact is highlighted most clearly during these years. Later the ecosystem adapts to the introduced species, and its positive or negative effect weakens while its impact on the biodiversity becomes chronic (long-term).

All the cases of introduction in the 20^{th} century are related to anthropogenic activity. We would like to mention only two plankton species (*Copepoda aquaedulcis*, *Acartia clausi*) and Ctenophore (*Mnemiopsis leidyi*). The first two species can be an example of a positive introduction as they are used as a food base by plankton-feeding fish and increase the value of the Caspian zooplankton. As for the Ctenophore, this species is an example of a negative impact on the biodiversity of the Caspian (Ivanov et al, 2000). The species eats out zooplankton and causes starvation for the plankton-feeding fish.

Consider a role of introduced species in the ecosystem of the Caspian and their impact on its biodiversity. We believe that to dramatize the impact of introduction is not right. As highlighted above, the present community of the Caspian contains mainly introduced species that form its rich biodiversity. However, the Caspian is not open to any exotic species that get into it. There is no doubt that such introduced species as Ctenophore needs to be neutralized.

There is no doubt that the most ancient introduced species in the Caspian should be protected against any negative impact, including the impact of new introduced species. The Caspian indigenous flora and fauna are the main value of this continental water body. These living fossils are of high biological, ecological, genetic and commercial importance. Some surveyors believe (Dumont, 1998; Zonn, 2000; Aladin and Plotnikov, 2000) that biological resources of the Caspian are more valuable than its oil and gas resources. We would like to outline that the most valuable fish is Caspian indigenous sturgeon that is the descendant of inhabitants of the ancient ocean Tethys.

We are positive about aimed introduction of species into the Caspian. Introduction of Polychaeta *Nereis* and bivalve *Abra* were done as recommended by the scientists (Karpevich, 1975). It significantly increased value of the Caspian benthos as a food base. Adaptation of mullet and flounder was also successful. There can be more perspective introduced species in the area. The opinion to reject any introduction of the species into the Caspian is not correct. Due to specifics of its formation, this great lake has free econiches that can be filled by people. New aimed introductions in the Caspian should not put us off.

A range of accidental introductions appeared to be commercially useful. Many microscopic Crustaceans increased the value of the Caspian plankton as a food base; shrimps increased the value of benthos. A high amount of accidental introduction did not have any significant impact on the biodiversity of the water body. However, some of them such as *Balanus* and bivalve *Mytilaster* had a certain negative impact from people's point of view. The above mentioned organisms cannot be used as food for fish because of their thick shells; they are typical representatives of non-food benthos.

The impact of climate changes on the biological diversity of the Caspian is not well studied. The majority of the surveys relate to the field paleontology. In other words, these are the studies of ancient climate changes impact on fossils that used to inhabit water bodies that were in the place of the Caspian. The majority of the scientists believe that climate changes impact on the biodiversity of the ancient Caspian was indirect, through climate impact on the sea level and its salinity. Climate changes induced the sea level and salinity changes of the ancient Caspian. These changes significantly altered the biodiversity of the water body. Nowadays we know (Rodionov, 1994) that fall of temperature causes the sea level raise, while rise of temperature causes decrease of the sea level and increase of salinity. Thus, during the period of transgressions at the Caspian, fresh-water and originally fresh-water species dominated, while the abundance of marine salt-loving species reduced. Marine species would only survive in the most saline parts of the ancient Caspian. During regression the situation was the opposite. Salt-loving species used to dominate while fresh-water species would survive only in deltas and adjacent areas of ancient Caspian rivers. There were periods in paleolimnological history of the Caspian when sudden and severe changes of climate caused such significant changes of the seal level, salinity and temperature that many ancient species were lost. It is worth mentioning though, that such catastrophes did not occur often, and some species managed to survive and to rehabilitate the biodiversity during the process of evolution. Thus, the evolutionary line of the Caspian indigenous species never broke in the Caspian. Therefore so many living fossils inhabit this unique water body.

At present climate changes also have their indirect impact (through the sea level changes and salinity) on the biodiversity of the Caspian. Of course, this impact is very weak and less obvious than the above-mentioned examples of climate changes impact on the biodiversity during the previous geological periods.

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